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ABSTRACT

The purpose of the conference reported in this document was to bring together national leaders in teacher education to disseminate findings and innovations in the reform of elementary teacher preparation in mathematics and science. The proceedings begin with a presentation of invited addresses: "New Curricula in Elementary Mathematics: What Are the Critical Factors?" (Shirley M. Frye); "The Reform of Elementary School Science: The Critical Issues" (Roger W. Bybee); and "The Integration of Content and Pedagogy in Teaching" (Hilda Borko). The proceedings then present 11 project summaries. Papers form 8 panel sessions comprise the main body of the proceedings; panel themes are teacher knowledge issues, special issues in teacher preparation, and institutional coordination issues. The panel session titles are: (1) Developing Teachers' Mathematics and Science Content Knowledge; (2) Developing Teachers' Pedagogical Knowledge; (3) Developing a Cohesive Program; (4) Underrepresented Groups in Mathematics/Science; (5) Technology in Science and Mathematics Education; (6) School and University Collaboration; (7) Promoting University Faculty Development; and (8) Establishing Administrative Support. The document concludes with an ethnographic summary, "An Interpretive Account of a Conference on the Preparation of Elementary Teachers of Science and Mathematics" (Kenneth G. Tobin). Three appendices provide the conference agenda and lists of conference presenters and conference participants. (LL)

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CRITICAL ISSUES IN REFORMING ELEMENTARY TEACHER PREPARATION IN MATHEMATICS AND SCIENCE

CONFERENCE PROCEEDINGS

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Most of all, we are *especially* indebted to the participants, who took time from busy schedules to attend the conference; and to the presenters, who created outstanding presentations and proceedings papers. The presenters' cooperation, flexibility, and ingenuity allowed us to be responsive to the needs of the participants. Thanks for a great job!

Finally, we acknowledge the invaluable contributions of our ethnographer, Ken Tobin, Florida State University and the excellent ideas and resources provided by the National Science Foundation, and Program Officers Miriam Leiva, Glenda Lappan and Lois Nicholson.

Kathryn F. Cochran , Educational Psychology
April L. Gardner, Biological Sciences

Although the papers included in this proceedings are based on those presented at the UNC Critical Issues Conference with funding from the National Science Foundation, the opinions expressed herein do not necessarily represent the position or policy of the National Science Foundation, and no official endorsement by NSF should be inferred.

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INTRODUCTION

The purpose of this project was to bring together national leaders in teacher education to disseminate findings and innovations in the reform of elementary teacher preparation in mathematics and science. The conference was designed to address the following six major goals:

- To identify and disseminate innovations in preservice elementary teacher preparation in mathematics and science developed by current major NSF-funded projects and by others.

- To encourage development of appropriate mathematics, science, and pedagogy courses for preservice elementary programs, including topic selection, course syllabi, and materials.

- To disseminate methods of program evaluation and assessment, and systems for administrative support and university faculty development.

- To demonstrate novel uses of technology in teacher education programs and to encourage effective preparation of teachers in classroom applications of such technology.

- To identify ways to help elementary teachers apply multicultural perspectives in the classroom, foster interests of girls and minorities in science and mathematics, and encourage recruitment of minority teachers.

- To produce a Conference Proceedings publication to serve as a reference to guide the revision and reform of elementary teacher preparation programs nationally.

Conference presenters were drawn from project directors and faculty of six NSF-funded preservice projects at Indiana University, Kansas State University, Mississippi State University, University of Northern Colorado, University of Northern Iowa, and the University of Wyoming. Other NSF-funded projects were also represented by Deborah Ball, Michigan State University; James Copl, Madonna University; Elizabeth Goldman, Vanderbilt University; and Kathleen Fisher, San Diego State University. Overviews of these projects are presented in the section in these proceedings entitled "Project Summaries". Invited addresses were contributed by Shirley Frye, Past President of NCTM, Rodger Bybee, BSCS, and Hilda Borko, University of Colorado. Other invited presenters included Bonnie Brunkhorst, Past President of NSTA; Carolyn Cody, UNC Special Assistant to the Vice President; John Halcón, UNC Foundations of Education; and Anthony Evans, California State University - San Bernardino and the Renaissance Group. Kenneth Tobin, Florida State University, served as conference ethnographer and evaluator. In total, 42 presenters took part in the conference.

In the summer before the conference, invitation letters were sent to the Deans of the College of Education and the College of Arts and Sciences at 100 non-doctoral institutions preparing large numbers of elementary teachers, identified using AACTE data. These universities were asked to apply by nominating a three-member team to attend the conference, composed of individuals from three of the following four groups: mathematics faculty, science faculty, education faculty, and administrators with relevant academic training. The goal was to invite institutions preparing large numbers of teachers and interested in learning more about major reform efforts, and to stimulate the formation of "core groups" at those colleges and universities that would have the greatest impact on teacher preparation reform. Institutions preparing large numbers of minority teachers were targeted for approximately ten of the thirty available slots.

Applications were received from 60 institutions, and 35 of those designated an appropriate three-member team. With NSF approval, the number of teams to be funded was increased from 30 to 35. All these institutions were invited to attend, resulting in a total of 105 NSF-supported participants. Five additional institutions sent representatives at their own expense, and the total number of registered conference attendees was 136. Since the conference sessions were also open to local and regional educators and faculty, the attendance at some conference sessions was as high as 250. It was estimated that the total number of teachers prepared each year by the institutions represented at the conference was approximately 15,000.

The conference sessions were held October 10-13, 1991 in the newly-renovated University Center at the University of Northern Colorado and at a local hotel conference center. The conference format included large group panel sessions that were followed by break times and then by concurrent sessions that were designed to allow the participants to interact more closely with each other and with conference presenters.

The conference presentations were organized around seven major issues in elementary teacher preparation. They included the following:

- Developing Teachers' Mathematics and Science Knowledge
- Developing Teachers' Pedagogical Knowledge
- Developing a Cohesive Program
- Underrepresented Groups in Mathematics and Science
- Technology in Science and Mathematics Education
- Schools and University Collaboration
- Promoting Faculty Development
- Establishing Administrative Support

The papers in these proceedings were written by the presenters, and superficially edited by the conference organizers. Formats and fonts were changed to a common style, and a few spelling, wording, and grammatical changes were made. In a few cases a table or figure was retyped. Every effort was made to retain the intended meaning; however, we do take responsibility for any mistakes made during the translation process from the original documents.

We were excited and pleased by the interest and innovative ideas demonstrated by participants throughout the conference. Informal conversations with NSF project officers indicate that a number of participants have acted on their commitments to elementary teacher preparation in science and mathematics by developing proposals for reform at their own institutions. These proposals and the initiatives described in these proceedings indicate that the reform is well on its way! We hope that these ideas continue to stimulate interaction, discussion, controversy, coordination, collaboration, and clarification of issues in the preparation of elementary teachers in mathematics and science among teacher education faculty in science, mathematics, and education, and among university and school administrators and teachers.

* * *

INVITED ADDRESSES

NEW CURRICULA IN ELEMENTARY MATHEMATICS: WHAT ARE THE CRITICAL FACTORS?

Shirley M. Frye
Past President, National Council of Teachers of Mathematics

THE REFORM OF ELEMENTARY SCHOOL SCIENCE: THE CRITICAL ISSUES

Rodger W. Bybee
Biological Sciences Curriculum Study

THE INTEGRATION OF CONTENT AND PEDAGOGY IN TEACHING

Hilda Borko
University of Colorado

NEW CURRICULA IN ELEMENTARY MATHEMATICS: WHAT ARE THE CRITICAL FACTORS?

Shirley M. Frye
Past President, National Council of Teachers of Mathematics

A careful study of the titles and themes of this conference will convince you that the best kept secret across the nation is the significant number of changes that are occurring in teacher education programs in mathematics and science. Another indication of this is found in the booklet, *Preparing Elementary School Mathematics Teachers: Readings from the Arithmetic Teacher*, Joan Worth, NCTM 1988. This anthology of articles reveals the creative approaches that have signaled teacher preparation programs often as models of change for almost three decades.

But, during this decade teacher preparation has been one of the 'whipping boys' for the deficits in school mathematics despite a very complex set of societal factors and classroom conditions that all contributed to the problems.

Congratulations to the conference coordinators for featuring the projects that will be part of the solutions! It is our good fortune to be here to share and learn from each other.

I want to thank you for being a teacher. . . a teacher of teachers. A favorite quote of mine is, "Those who can, teach; those who cannot, do something far less significant." Currently in mathematics education the focus is on not only the WHO, but the WHAT and the HOW. HOW mathematics is taught is just as important as WHAT is taught.

The visionary leaders in the reform movement stress that students' ability to reason, solve problems, and use mathematics to communicate their ideas will develop only if they actively and frequently engage in these processes. Whether students come to view mathematics as an integrated whole instead of a fragmented collection of arbitrary topics and whether they ultimately come to value mathematics will depend largely on HOW the subject is taught.

The need to change, to improve, and to be responsive to societal factors has always been prevalent in education. But, the response today in mathematics education is much more pervasive and better orchestrated than ever before. The leadership and direction for reform are emanating from the grass roots, the educators themselves, with designed involvement of all levels of professionals and the intentional recruitment of support from a host of enabling groups.

The realistic consideration of curriculum, evaluation, and instruction simultaneously has impact for all levels of mathematics education from preschool thru K- 16 to graduate school. The coordinated efforts with common themes and interrelated recommendations come from the total mathematics and mathematics education communities. The consensus of recommendations are found in these documents:

Curriculum and Evaluation Standards for School Mathematics
Professional Standards for Teaching Mathematics
National Council of Teachers of Mathematics

Everybody Counts
Reshaping School Mathematics
Mathematical Sciences Education Board

Call for Change
Mathematical Association of America

A compelling statement in the *Call for Change* addresses the theme of this conference,

> Substantive changes in school mathematics will require corresponding changes in the preparation of teachers. Prospective teachers must have opportunities in their collegiate courses TO DO MATHEMATICS: explore, analyze, construct models, collect and represent data, present arguments, and solve problems.
>
> The collegiate level course must reflect the changes in emphases and content of the emerging school curriculum and the rapidly broadening scope of mathematics itself.

In reviewing the *Curriculum and Evaluation Standards for School Mathematics*, you will find the guidance for developing a well balanced curriculum with matching assessment. The Standards in K-4 and 5-8 include the familiar strands of geometry, pattern, measurement, estimation, and computation, but feature them differently. They are seen through a lens that illuminates the weaving of the common threads of problem solving, reasoning, communicating, and making connections in every topic.

Studies have shown that about 85% of class time in elementary school is now spent on drill and practice of computation skills. Placing computation in the proper perspective as only one part of an elementary curriculum is apparent in the list of key strands for inclusion in the recommended program. The Standards give guidance for areas of increased and decreased attention and emphasize that skill development be nested in the context of problem solving.

These themes are addressed in the context of instruction and professional development in the companion document, the *Professional Standards for Teaching Mathematics*. In it the assumptions about teaching mathematics at every level are:

- the goal of teaching mathematics is to help all students develop mathematical power
- what students learn is fundamentally connected with how they learn it
- all students can learn to think mathematically
- teaching is a complex practice and hence not reducible to recipes or prescriptions.

Two very important assumptions that speak directly to teacher preparation and that this conference program addresses are:

- teachers are influenced by the teaching they see and experience.
- the teaching envisioned in the Standards differs significantly from what many teachers have experienced themselves as students.

As a consequence there are characteristics of the emerging curriculum that are critical to the preparation of prospective teachers who will be expected to implement the reformed programs in elementary school. I will elaborate on manipulatives, technology, number sense, and assessment, but will expect that broad topics like constructivism will be considered in your continued attention to reforming your programs.

Use of Manipulatives

There are many dimensions to planning and managing mathematics instruction that involves manipulatives to develop understanding. Most important is the selection and use of manipulatives that correctly represent mathematical topics. Another is the assessment of students' thought processes as they use the manipulatives. Teacher preparation programs must provide experience in these aspects of decision-making related to manipulatives.

In his article, *Hands On: Help for Teachers,* Cecil Trueblood, Penn State University reminds us of the absolute necessity of math labs and practicums built around experience with manipulatives. He says, "Prospective teachers use manipulatives in their teaching in the same manner in which they were taught."

Use of Technology

The calculator should be a common tool to extend student thinking, to calculate accurately and efficiently with real data, and to promote patterning and conjecturing. The computer affords the opportunities to simulate, investigate, and connect mathematics to science, social studies, fine arts and other areas. With interactive capabilities and tools, like hypercard, new vistas are opening to integration, communication, and utilization of all modalities of learning.

The potential of these valuable tools demand that using technology must be part of the pre-service program as an integral part of content and pedagogy.

Number Sense

This is not another topic, but the development of a common sense approach to using numbers complemented by an intuitive feeling for numbers and their uses. Teaching for number sense focuses on students and their solution strategies, rather than on a "right answer," on thinking rather than on the mechanical application of rules, and on student generated solutions rather than on teacher supplied answers. I believe that the phobic reaction to mathematics for multitudes of learners . . . and elementary teachers. . . stems from the lack of opportunities to develop this intuitive number sense.

Let me use an example that illustrates how necessary it is that number sense be used to give the answers to a computation in context. First, think of the possible answers for this division, 32/7. Now match the answers or find appropriate ones for these problems.

A. I have $32. Tickets cost $7. How many can I buy?
(Wouldn't you agree that 4 tickets is correct?)

B One adult is needed for every seven students on a field trip. There are 32 students. How many adults are needed?
(Certainly, 5 adults is the wise choice!)

C. The tank needs to be cleaned every 32 days. How many weeks is that?
(4 weeks and 4 days or 4 4/7 weeks)

D. Sally received $32 for wrapping packages. She worked for 7 hours.
How much did she earn per hour?
(Her hourly rate was $4.57.)

Each computation was interpreted by the context of the problem which gave meaning to the various answers.

Assessment

The Standards propose that student assessment must be integral to instruction and aligned with curriculum. One needs only look at the list of multiple means of assessment methods to acknowledge the complexity of this component of teaching. The attention given to all the aspects of designing instruments. Analyzing individual's understanding, interpreting results, and modifying instructional strategies must be maximized in teacher preparation programs.

From this brief overview, we see that the challenge to consider these components of content and pedagogical knowledge in new and creative ways is a vital part of this conference. In both science and mathematics preservice programs our views of tasks, environment, discourse, materials, representations, instructional strategies, classroom organization, and assessing student understanding will alter teacher preparation.

Among the many challenges will be the obligation to make future teachers aware of the inhibitors to change that they will face in their initial teaching assignments:

- lock step 50 minute periods
- mandated strategies and standardized testing
- reliance on textbook curricula
- beliefs that differences equal deficiencies
- rigid scope and sequence requirements
- minimal expectations for the majority of students
- commitment to the status - quo.

This practical reality of schooling and the demands of teaching should be balanced with our support of teachers in their induction period. We are also obligated to reinforce them and enable them to maintain their enthusiasm for the new skills and instructional practicums we have provided.

If mathematics education instruction is to enable all students to experience mathematics as a dynamic engagement in solving problems, then certainly many educators must rethink their perceptions. What is mathematics? How is mathematics learned? What is a mathematics class like? Who should be expected to learn mathematics? This rethinking is indeed crucial to the reform at every level.

A continuing challenge to you in teacher preparation is to modify your programs to provide prospective teachers with experiences that will equip them to be the reformers of school mathematics.

Summary

MATHEMATICS TEACHERS of the 1990's and the next century must:

- communicate mathematical ideas with ease and clarity
- organize and analyze information to formulate and solve problems readily
- possess knowledge of learning theory and instructional strategies
- have an understanding of mathematics that is considerably deeper than that required for the school mathematics they will teach
- use technology naturally and routinely in the learning, teaching, and doing of mathematics.
- enjoy mathematics and appreciate its power and beauty.
- understand how mathematics permeates our lives and how the various threads within mathematics are interwoven.

Certainly then, teachers with these abilities will make our vision of mathematical power for all students a reality. This will be possible because teacher preparation focuses on all three critical factors, WHO, WHAT, and HOW in mathematics and science preservice programs.

THE REFORM OF ELEMENTARY SCHOOL SCIENCE: THE CRITICAL ISSUES

Rodger W. Bybee
Biological Sciences Curriculum Study

As many individuals continue proclaiming the emerging reform of science education, they present as examples of reform policy statements such as *Science for All Americans* (AAAS, 1989), the *Science Framework for California Public Schools-Kindergarten Through Grade Twelve* (California Department of Education, 1990), and *Essential Changes in Secondary School Science: Scope, Sequence, and Coordination* (NSTA, 1989). I suggest there could be a different declaration. The reform of elementary school science is already here and there are examples of programs, such as NGS-Kids Network from TERC, *Improving Urban Elementary Science: A Collaborative Approach* from EDC, *Full Option Science System* (FOSS) from Lawrence Hall of Science, and *Science for Life and Living* from BSCS. These programs and others that will soon be available are more than political rhetoric and policy statements, they exist, they are available, and they make the reform of science education a reality for many school systems and elementary teachers.

These new programs are not like earlier programs, such as SCIS, ESS, and S-APA and they are not like the textbook programs that are in most elementary schools. There are some characteristics that science educators must address (see Figure 1). This essay addresses two major questions--What are the distinguishing characteristics of the new elementary programs? And--What are the critical issues relative to the reform of elementary school science?

Characteristics of New Science Curricula

Why new science curricula for elementary school? The short answer is that the 1990's are not the 1960's. The longer answer that innovations in science and technology, advances in philosophy and psychology, and new aspirations of society have placed different demands on science education. A major indicator of the need for new curricula is the continuing feedback from society to all of us indicating that achievement of students is below expectations. Many of us are all too familiar with the mountains of reports demanding reform. The revision of curricula developed in the 1960's or using current textbook programs cannot

FIGURE 1
CONTEMPORARY ELEMENTARY SCHOOL SCIENCE

PROJECT TITLE	ORGANIZATION	PRINCIPAL INVESTIGATOR PROJECT DIRECTOR	FUNDING	PUBLISHER	PROGRAM	GRADES	INNOVATIONS
Improving Urban Elementary Science	EDC	Worth (PI) Sandler (PD)	NSF	Sunburst	Stand-Alone Modules	K-6	Instruction Model Activity Based Cooperative Learning
Full Option Science System	LHS	Lowry (PI) DeLucchi (CoPD) Malone (CoPD)	NSF	Encyclopedia Britannica	Articulated Modules	K-6	Activity Based Integrated with Other Disciplines
NGS-Kids Network	TERC	Tinker (PI)	NSF	National Geographic	Stand-Alone Modules	Upper Elementary	Activity Based Telecommunicate
Science For Life and Living	BSCS	Bybee (PI) Landes (PD)	NSF	Kendall/Hall	Comprehensive K-6 Program	K-6	Instructional Level, Activity Based Cooperative Learning
Super Science	Scholastic	Chapman (PI)	NSF	Scholastic	Magazine Form 1-6	1-6	How-To Activities
Life Lab Science Program	Life Lab	Appel (CoPI) Jaffe (CoPI)	NSF	Videodiscovery	Comprehensive K-6 Program	K-6	Activity Based
The Science Connection	Houston Museum of Natural Science	Sumners (CoPI) Contant (CoPI)	NSF	Selver, Burdett, and Ginn	Supplementary 1-6 Program	1-6	Hands-On Activity Reader AV Materials

accommodate those demands. The new programs are partial answers to the need for reform and examples of how elementary school science in the 1990's is different from earlier programs. The following discussion highlights several prominent characteristics of new science curricula.

Conceptual Change. An increasing understanding of how students learn is having a pronounced effect on educational reform. The early investigation of Jean Piaget provided the foundation for current research in psychology, cognitive science, and science education. There is wide agreement that learners actively construct a world view based on their observations and experiences, including those of formal instruction in schools, they use pre-existing concepts to interpret and explain their current experiences. Because these currently explanations often differ from the concepts presented in formal science education--the scientific view of the world--researchers and science educators must answer the question, "How does one change students' misconceptions and naive theories so that each student's understanding becomes more aligned with that of science?" (Carey, 1986; Champagne & Klopfer, 1984; Linn, 1986; Novak, 1988).

Curricular and instructional approaches that encourage conceptual change are different from textbook programs now used in the majority of elementary schools and from instructional activities in most school programs (Weiss, 1987). Reading about science, telling students the scientific view, demonstrating science principles and lecturing on scientific concepts are inadequate methods to bring about conceptual change. Research supports the view that teachers must first challenge the adequacy of students' current conceptions, then students must have the experiences and time required for them to reconstruct more adequate explanations (Champagne, 1987; Anderson, 1987).

Incorporating contemporary views of learning is a challenge for curriculum developers and classroom teachers. The instructional issues relate to the sequence of instructions and the nature of activities. For the learner, instructional activities must ensure engagement in the concepts, offer a challenge to current concepts, provide awareness of the specific concepts being questioned, and afford time and opportunity to reconstruct the concepts. The nature of the activities and approaches must be such that they are meaningful for students, students have time to explore ideas, become acquainted with scientific or technologic concepts and evaluate their adequacy. Several new science programs for elementary schools used these criteria in designing and incorporating instructional models.

Let me digress to describe two critical issues about instructional models. The first issue has to do with the meaning an activity within the instructional sequence has for students. An activity can have meaning because objects and events are physically close. Having hands-on experiences and engaging in activities both have a dimension of personal meaning. There is a second dimension that I think of as psychological meaning. There are some objects and events that are interesting and engaging for children. Dinosaurs, plants, and solar system are all examples. Instruction can use the initial interest in these areas to develop concepts, such as time, cycles, and scale. Finally, there is a social aspect of meaning. This is the dimension that most individuals associate with meaning. They equate meaning with relevance or the timeliness of issues. In some cases, science-related social issues, such as population growth, environmental pollution, or resource depletion are meaningful to students; but, assuming these are meaningful just because they are timely, and even critically important, is not always a correct assumption from a learning point of view. Obviously, combining all three dimensions of meaning certainly enhances the possibilities of learning.

There is a second critical issue regarding instructional models. I am now convinced that an instructional model such as the one we use in the BSCS program *Science for Life and Living* is necessary but not sufficient for the process of conceptual change. That is, the careful structuring and sequencing of activities is a tremendous help in bringing about conceptual change. There remains, however, a critical interaction between students and teachers that completes the process in the context of classrooms and schools. A carefully structured sequence of activities enhances the possibilities of learning, but it does not ensure learning. The careful probing by teachers, subtly challenging the students, and knowing when to provide a hint or clue that will help the student reconstruct an idea are all interpersonal dimensions of instruction the cannot be adequately accommodated by a set of activities.

Conceptual Economy. If it takes more time to learn concepts, science programs should contain fewer concepts. The concepts used to design new programs should have conceptual richness, power, and integrity across disciplines. Science educators characterize this curricular issue as "depth vs. breadth" (Linn, 1986; Newmann, 1988). Actually, the issue is not new; it has been around for some time. What is new, however, is the development of curriculum materials that provide students deeper involvement in exploring and defining important concepts for themselves. Superficial coverage of topics--as is evident in contemporary textbooks--leaves students with little sense of understanding and accomplishment, fewer opportunities for problem solving and less development of skills.

If one is going to include fewer concepts, then which concepts ought to be part of the curriculum? At least two criteria should guide the content selection: the knowledge selected should be fundamental to the structure of scientific disciplines and it should represent an integration across disciplines.

In the 1960's, most major projects carefully assessed concepts that represented the structure of the disciplines. Some of those same concepts are still applicable. Today, there must be some effort to identify concepts that integrate science disciplines and other disciplines, such as technology, health, and social studies (Hurd, 1986; Bybee, 1987). This is a difficult set of criteria; inevitably, curriculum developers omit some important concepts. However, teachers should develop confidence that learning less may mean learning more.

Science for All Students. One common theme in new programs is that they address the needs of all students. This is in contrast to the 1960's when the programs primarily addressed science-prone and college-bound students. Addressing the needs of all students is a complex issue, but the earlier discussion of student learning provides some insights and potential solutions.

Learners build on prior knowledge, and that knowledge has its origins in experiences and observations. Obviously, different students have different world views. The knowledge base of students with fewer science experiences and different observations sets the stage for initial, and then continued, problems. In particular, the lack of exposure to experiences in science and technology that girls, minority groups, and disabled students get may hinder their development of adequate and useful world views and a scientific knowledge base.

New programs address students' needs in two important ways. The activities in the instructional sequence accommodate diverse backgrounds and provide opportunities for students to construct new conceptual structures. Incorporating cooperative learning into the curriculum is another way of addressing student diversity. For example, cooperative learning is not ancillary, it is integral to the BSCS program. This program uses the cooperative learning model developed by Roger and David Johnson and their colleagues (Johnson & Johnson, 1987; Johnson, Johnson & Holubec, 1986). I especially note research indicating the positive contributions of cooperative learning as it relates to diverse student groups (Johnson, Johnson & Maruyama, 1983; Johnson & Johnson, 1975; Johnson & Johnson, 1987).

Implementation. In the 1960's, the primary approach to implementation was National Science Foundation institutes. The effectiveness of this approach to the actual use of new programs is not clear, especially at the elementary level. We do know that the programs of the 1960's were not long lasting and did not replace the textbook as the primary means of science instruction (Weiss, 1978). Between the 1960's and 1980's, research on implementation has appeared in literature (Fullan, 1982; Hall & Hord, 1987; James & Hord, 1988). Implementation is a significant consideration in the development of the new programs. I fully recognize the complicated nature and time it takes to implement an innovative program. Teachers must understand the pedagogy, they must learn the logistics and philosophy of the program, and they must receive adequate administrative support to help them through the changes inherent in adopting a new science program. A portion of the responsibility for full implementation belongs to curriculum developers; the curriculum must be complete, accurate, and clearly written. Another portion of the responsibility belongs to teacher educators; beginning teachers must be aware of the new programs, understand the content and pedagogy, and be able to manage classrooms where active learning is occurring. A final, and absolutely essential, portion of the responsibility belongs with the school districts. One lesson from the programs of the 1960's is clear--unless there are mechanisms developed at the district level--plans for long-term staff development and administrative support, the new programs do not succeed (Bybee, 1988).

Critical Issues and the New Science Curricula

There are many critical issues surrounding the new programs for elementary school science. From my perspective, there is only one absolutely critical issue and that is the appropriate implementation of new science curricula. There are, of course, many dimensions and interpretations of the phrase "appropriate implementation." In general, I take appropriate implementation to mean that a school system selects a program that is right for that school and that the program is implemented and used with fidelity. That is, if the program has features such as activities based on technology, an instructional model, and cooperative learning, these are used in the way the curriculum developers intended. An inappropriate implementation would be to adopt a new program and ignore the philosophy and pedagogy of the program. Using NGS-Kids Network without the technology or the BSCS program without the instructional model would, in my view, be examples of inappropriate implementation. Implementation is the process that results in the institutionalization of the new program in school system. I address some specific issues in the following sections.

Making the New Curricula Visible. Many educators do not see the new programs. The situation reminds me of Ralph Ellison's book *Invisible Man* (1952). In the prologue to the book, Ellison, a black man in white society, makes this statement:

> I am invisible man. No, I am not a spook like those who haunted Edgar Allan Poe; nor am I one of your Holly-movie ectoplasms. I am a man of substance, of flesh and bone, fiber and liquids--and I might even be said to possess a mind. I am invisible, understand, simply because people refuse to see me. (p. 3)

The media blitz surrounding educational reform, the marketing strategies of commercial publishers, and the dominance of state and local syllabi have the unintended result of looking past new programs that do exist and do have many innovative characteristics. Like the invisible man, new science curricula for elementary schools are available, but they are not seen.

As I suggested above, the new curricula are here, they are available, they have been implemented in some school systems. However, they still remain invisible due to attention on major policy documents such as *Science for All Americans* (AAAS, 1989). Yet, the reality is that school systems are adopting elementary programs or developing their own programs. Although policy statements contribute to both adoption and development, most districts and many states require programs.

Resolving these issues includes developing an awareness and understanding of the characteristics of new programs. School personnel need more than an introduction to the new programs, they need experience with fundamentals, such as constructivist teaching strategies, technology, major conceptual ideas, and management of activity-based programs.

The critical issue is that diverse programs are available and they should become visible in teacher preparation and professional development programs. There is a shared responsibility among curriculum developers, teacher educators, and commercial publishers for alleviating making the new programs visible.

Adapting the New Curricula. Some educators approach adopting a new curriculum like an organ transplant. Unfortunately, many have the misperception that you can simply open the patient and insert the new organ without addressing such issues as a thorough assessment of the patient, adequate repression of the immune system, and evaluation of donor-recipient compatibility. When there is not thorough initial assessment of needs, there can be major complications before the transplant. Without donor-recipient compatibility, the transplant may not take from the beginning, and without adequate and sustained repression of the immune system, rejection occurs. There are a couple of additional very important notes about organ transplants. They require major adaptation or lifestyle changes and they require a lifetime of support.

Let me switch from the metaphor. There is a science program in most school districts. The present program may not be readily available or widely used, but there is a program. The current program does have very powerful "prior knowledge" about what is an appropriate science program. Now many local districts are rethinking their syllabus for elementary school science. The typical approach is to form a committee, to meet several times, and to develop a policy statement for the school district. School personnel base these policy statements on varying degrees of research and reference to position statements form national organizations such as NSTA and policy documents from professional groups such as AAAS. Often, the original intention of the district is to develop a full program. Usually, there is neither time nor resources to develop a new curriculum, so district personnel look for a program that exists. Here is the critical point--the extant program and work on new policies, not to mention politics and personalities, forms a dominating image of an acceptable program. When school personnel review new curriculum materials, there is often an either/or evaluation of the new curriculum. That is, either there is a one-to-one correspondence of the national program with the local syllabus or the school system rejects the program. The school personnel fail to recognize the possibility of changing both the syllabus and program and they do not factor in professional development as a process for adapting both teaching styles and curriculum materials.

This issue can be alleviated by approaching adoption as one of adapting both the local syllabus and the new programs. My hunch is that the process of adapting extant materials would enhance elementary school science education in the district.

Sustaining New Curricula in School Systems. There are many people who begin exercising for a variety of reasons. They begin walking, jogging, aerobics, cycling, and a variety of other activities often with the intention losing weight and improving health. Have you ever wondered why few people sustain the exercise program? There are probably a variety of reasons, such as the initial workouts are inconvenient. Now, there are some helpful hints, such as begin with a less difficult workout, use good equipment, and rearrange personal and work schedules. There must be a strong motivation to change and there must be enough support to sustain the change in lifestyle. So it is with the change in teaching style required of new innovative curricula.

A single teacher, especially a new teacher, cannot reasonably be expected to implement a new program in a school system. The teaching style changes required of new programs need the support of peers, administration, and the community.

Conclusion

Developing new curricula for elementary school science is only one small step in the reform of American education. The burden of reform reaches to all educators and citizens. The burden is especially heavy on classroom teachers since this is where the most fundamental reform must occur. Although I see no way to reduce the reality of changing classrooms, I do recognize the absolute requirement for systemic support from scientists, science educators, school administrators, and parents. With support within and outside of the educational system, there is the possibility of change and improvement in American education.

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THE INTEGRATION OF CONTENT AND PEDAGOGY IN TEACHING

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As the title of this presentation indicates, I will talk tonight about the integration of content and pedagogy in teaching. More specifically, my remarks will focus on the construct, pedagogical content knowledge. I will address three major questions:

1. What is pedagogical content knowledge?
2. What are the components or dimensions of pedagogical content knowledge?
3. How can we help novice teachers to increase their pedagogical content knowledge?

What Is Pedagogical Content Knowledge?

What is pedagogical content knowledge? This question is not an easy one to answer, and it is one for which there is some amount of disagreement within the professional literature. To my knowledge, the term was first used by Lee Shulman and his colleagues in the Knowledge Growth in Teaching project. Shulman offered the following definition:

> Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations--in a word, the ways of representing and formulating the subject that make it comprehensible to others....Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. (Shulman, 1986, p.9)

This definition implies that although pedagogical content knowledge develops from an integration of knowledge from several domains, it is a distinct domain within the professional knowledge base of teaching. In fact, the question of whether pedagogical content knowledge is or is not a unique knowledge domain is one that has received a fair amount of attention within the educational research community. And, there is not consensus on the answer. In recent years, several models of the professional knowledge base of teaching have been proposed. Some of these models include pedagogical content knowledge; others do not. People who do use the construct--those of us who consider pedagogical content knowledge to be a unique knowledge domain--are not arguing that it is a discrete domain, non-overlapping with others. From my perspective, a metaphor used by Rick Marks, a mathematics educator and former student of Shulman's, captures well the relationship between pedagogical content knowledge and other domains of teachers' professional knowledge. Marks wrote:

> A geographical metaphor may be useful. Three neighborhoods in San Francisco border on one another....[Each] of the three has a distinct identity. On the fringes of these neighborhoods, in the residential areas between their "downtowns," the populations are heterogeneous, and the identities are blurred. The streets perceived as "boundaries" are somewhat arbitrary with respect to neighborhood characteristics. Similarly, some instances of teacher knowledge clearly represent one or another type, but many fall on the fringes. Any precise demarcation of pedagogical content knowledge from subject matter knowledge and general pedagogical knowledge is somewhat arbitrary.... (Marks, 1990, p. 9)

My position (as you have undoubtedly surmised) is that there is some value, both conceptually and practically, in considering pedagogical content knowledge to be a separate knowledge domain. Conceptually, I would argue that pedagogical content knowledge represents more than simply adding, or placing side by side, knowledge of content, pedagogy, students, curriculum, and educational aims. It is an integration of knowledge from those domains so that, to borrow a phrase from Gestalt psychology, the whole is more than the sum of its parts. Practically, if pedagogical content knowledge is considered to be a separate knowledge domain, it is more likely to receive explicit attention from researchers, practitioners, and policy makers. Such a focus on pedagogical content knowledge will help the educational community and the community in general to recognize and understand the unique knowledge and skills of the teaching profession, attributes of effective experienced teachers, differences between expert and novice teachers, and the process of learning to teach. It will also help us to design teacher education programs--both preservice and inservice--that more effectively facilitate the development of pedagogical content knowledge and, therefore, the process of learning to teach.

Tonight I will attempt to support these arguments. I will first present a more elaborated definition of pedagogical content knowledge and its components. Next, I will describe three teaching episodes that illustrate different degrees of strength of pedagogical content knowledge, and I will discuss each episode in terms of the components of pedagogical content knowledge. Finally, I will discuss what we know about the learning of pedagogical content knowledge, and I will suggest several implications for teacher education.

Before proceeding further with this exploration of pedagogical content knowledge I would like to acknowledge a number of people who have influenced my thinking in the area. Many of my ideas about pedagogical content knowledge were developed in long conversations with Joseph Krajcik, a science educator, when we were collaborating on several projects at The University of Maryland. These ideas were modified and revised through my work with colleagues on an investigation of Learning to Teach Mathematics funded by the National Science Foundation--Margaret Eisenhart, an anthropologist of education, and Catherine Brown, Robert Underhill, Doug Jones, and Patricia Agard, mathematics educators. Also, the work of, and conversations with, people such as Lee Shulman, Pamela Grossman, Deborah Ball, and Suzanne Wilson have substantially influenced my thinking. In fact, the definition of pedagogical content knowledge I present in the next section of the presentation is based on Pamela Grossman's work, and one of the teaching episodes is taken from Deborah Ball's writing about her own teaching of third grade mathematics. Without the benefit of colleagues' thinking and writing to draw upon, my ideas about pedagogical content knowledge would certainly be much less well-developed.

Defining Pedagogical Content Knowledge

At the beginning of this presentation I offered a general definition of pedagogical content knowledge as knowledge of subject matter for teaching. Pamela Grossman (1989, 1990) elaborated upon this definition by identifying and describing four central components of pedagogical content knowledge: overarching conception of teaching a subject, knowledge of instructional strategies and representations, knowledge of students' understanding and potential misunderstandings, and knowledge of curriculum and curricular materials. Dr. Grossman's conceptual framework for pedagogical content knowledge, developed through her work on the Knowledge Growth in Teaching project and her dissertation study of six beginning English teachers, is the focus of this section of the presentation.

Overarching conception of teaching a subject. According to Dr. Grossman's framework, one component of pedagogical content knowledge is an overarching conception of what it means to teach a particular subject. This conception serves as a "conceptual map" for instructional decision making, as the basis for judgments about classroom objectives, appropriate instructional strategies and student assignments, textbooks and curricular materials, and the evaluation of student learning. It seems reasonable to argue that strong pedagogical content knowledge is characterized by a well-developed overarching conception of what it means to teach a subject matter--a conception that is compatible with the most current thinking within a discipline and that guides the teacher in planning and implementing instruction.

It is my perception that teachers' overarching conceptions are receiving increasing attention from the educational community, particularly from national organizations for the teaching of various subject areas. One clear example is the National Council of Teachers of Mathematics, with its two recently published volumes: *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) and *Professional Standards for Teaching Mathematics* (NCTM, 1991). These documents address all components of pedagogical content knowledge (and much more). However, they begin with an overarching conception of what it means to teach mathematics, K-12. On page 1 of the *Professional Standards for Teaching Mathematics*, we read that:

> The image of mathematics teaching needed [to reach the goal of mathematical power] includes elementary and secondary teachers who are more proficient in--
>
> - selecting mathematical tasks to engage students' interests and intellect;
> - providing opportunities to deepen their understanding of the mathematics being studied and its applications;
> - orchestrating classroom discourse in ways that promote the investigation and growth of mathematical ideas;
> - using, and helping students to use, technology and other tools to pursue mathematical investigations;
> - seeking, and helping students seek, connections to previous and developing knowledge;
> - guiding individual, small-group, and whole-class work.

Knowledge of instructional strategies and representations. A second component of pedagogical content knowledge is knowledge of instructional strategies and representations for teaching particular topics. This is the component that Shulman addressed most extensively in his work. It is also the component that has been discussed and researched to the greatest degree.

The instructional tool that has probably received the most attention from educational researchers is the instructional representation--the model, example, or illustration a teacher uses to foster students' understanding of a specific topic. A few examples of instructional representations that come to mind from my own research are the collapsing can demonstration of air pressure; paper folding and tearing to illustrate multiplication and division of fractions; and use of a globe, yo-yo, and flashlight to demonstrate solar and lunar eclipses.

Deborah Ball (in press), one of the presenters at this conference, recently wrote about a related, but broader, concept that she refers to as the "representational context." As she explained, the representational context encompasses the terrain for investigation and development opened by a particular representation as well as the meanings and discourse it makes possible. The representational context encompasses the ways in which teachers and learners use the particular representation, how it serves as a tool for understanding their work. (pp. 5-6) The example from Dr. Ball's teaching that I will use later in the presentation illustrates this concept and the central role that it plays in her planning and implementation of instruction.

Strong pedagogical content knowledge is characterized by an extensive repertoire of powerful representations and the ability to adapt these representations in multiple ways in order to meet specific goals for specific sets of learners; in other words, the ability to construct multiple representational contexts for a single representation. Chris Clermont, Joe Krajcik and I discussed these aspects of pedagogical content knowledge as a teacher's "representational repertoire" and "adaptational repertoire" (Clermont, Krajcik, & Borko, in press; see also Shulman, 1987). Shulman (1986) wrote about the "veritable armamentarium of alternative forms of representation" that a teacher must have.

Knowledge of students' understanding and potential misunderstandings. A third component of pedagogical content knowledge is knowledge of students' understanding and potential misunderstandings of a subject area. This component differs from general knowledge of learners by virtue of its focus on specific content. In the subject areas of science and mathematics, for example, researchers have identified preconceptions, misconceptions and alternative conceptions commonly held by learners for topics such as division of fractions, negative numbers, heat energy and temperature, and photosynthesis. Teachers with well-developed pedagogical content knowledge are aware of the topics within a field that students are likely to find difficult, know what the common difficulties are, and have strategies for addressing those difficulties in their representational and adaptational repertoires.

Knowledge of curriculum and curricular materials. The final component of pedagogical content knowledge, as outlined in Grossman's (1989, 1990) framework, is knowledge of curriculum and curricular materials. Strong pedagogical content knowledge is characterized by an in-depth knowledge about the curricular materials available for teaching a particular subject matter, and about how the curriculum is organized and structured both horizontally (within a grade level or course) and vertically (across the K-12 curriculum) within one's own school system.

Please keep these four components in mind--overarching conception of what it means to teach a particular subject, knowledge of instructional strategies and representations, knowledge of students' understanding and potential misunderstandings, and knowledge of curriculum and curricular materials--as you listen to the descriptions of three teaching episodes which illustrate different degrees of strength of pedagogical content knowledge. I will follow each example with a brief analysis in terms of the four components of pedagogical content knowledge.

Teaching Episodes that Illustrate Pedagogical Content Knowledge

Dr. Ball's Teaching of Fractions

I have selected an episode of teaching fractions by Deborah Ball to illustrate strong pedagogical content knowledge. For several years, Dr. Ball has been teaching mathematics in a third grade classroom and documenting her teaching through various data sources such as audiotapes and videotapes of lessons, a teaching journal, and interviews of her students conducted by research assistants from Michigan State University. Today, I will draw from one of the experiences she has written about, the introduction to a formal unit on fractions. Her story of this introduction is presented in much greater detail in a chapter entitled, "Halves, Pieces, and Twoths: Constructing and Using Representational Contexts in Teaching Fractions" (Ball, in press).

Deborah Ball's initial deliberations on how to introduce the topic of fractions focused, in part, on "constructing a viable representational context." These deliberations drew upon knowledge from several domains, including knowledge of the mathematical content, students and how they learn, and the particular classroom setting. Thus, to construct her pedagogical content knowledge, Dr. Ball integrated knowledge from various domains in her professional knowledge base. In the chapter, she shares with the reader her thinking about each domain. The richness and detail of her deliberations prevent me from reproducing them in their entirety; however, I will provide a brief summary of her thinking related to each knowledge domain. With respect to content, Dr. Ball wrote, "In my journal, I worked on a conceptual map of fractions--the constructs entailed and the connections between fractions and other important mathematical ideas" (p. 15). She considered multiple interpretations of fractions; for example, as parts of a whole, numbers on a number line, quotients of integers, and ratios. Regarding curriculum, Dr. Ball considered the state and school district objectives for fractions and the information they provided about what third graders are expected to know. About learners, Dr. Ball wrote, "I also considered what nine-year-olds may have previously encountered about fractions--in school and out" (p. 17). Integrating her knowledge of third grade students, the district curriculum, and materials available at the school, she surmised that her students' prior experiences with fractions would be limited, consisting primarily of shading predivided regions. She also considered what she had learned about the children's ideas and thinking from listening to them in class when they worked on related topics such as probability. For example, she reread the notes in her journal about the ways in which different children reasoned in tasks like drawing one green chip from a cup containing both green and yellow chips. She concluded,

> I had seen little evidence that third graders had anything other than a fragile schoolish knowledge of thirds and fourths. Fifths, eighths, tenths, and so on, were basically unfamiliar and their understanding of halves, thirds, and fourths did not tend to set up the construction of other fractions. 'Half' was more a quantitative habit of mind than an explicit concept. (p. 21)

The first representation. Taking all of these factors into account, Dr. Ball decided to begin formal exploration of fractions by presenting the class with the following problem:

> You have a dozen cookies and you want to share them with the other people in your family. If you want to share them all equally, how many cookies will each person in your family get?

She explained,

> I conceived this problem as a thinking space in which I hoped to stimulate students to develop several key understandings of fractions. I used it on a cusp between an extended period of explicit work on multiplication and division (which had involved fractions) and the beginning of some direct work on fractions (which would continue to involve multiplication and division). The problem involved the partitive interpretation of division (forming a certain number of groups) and would produce multiple solutions. For some size families, there would be cookies left over which could be divided further. Based on what I knew about the families of my students, I realized that we could encounter fifths, sevenths, and probably halves and eighths. I also knew that students would probably be inclined to divide the leftover cookies, but would not necessarily know what to call the pieces they produced. Still, the children would probably see fifths and halves as clearly different in amount, hopefully motivating a need to name pieces in meaningful ways. I anticipated, in short, that this problem would launch us into an extended exploration of fractions. (p. 25)

In the chapter, Dr. Ball traced how various individual students worked to solve this problem and how she worked with the students by providing probes, prompts, and suggestions. She concluded the description of fractions by saying,

> We wended our way from the initial division-of-cookies problem into a serious exploration of fractions--as parts of wholes--including discrete sets, as numbers on the number line, and as operators. My decisions about representations--which to introduce, and how to structure their use, as well as how to respond to and shape the representations that the children brought--remained at the heart of my deliberations about the work. (p. 39)

Dr. Ball's pedagogical content knowledge. Dr. Ball's introduction to the unit on fractions reveals strength in all four components of pedagogical content knowledge. Her overarching conception of what it means to teach mathematics, although not explicitly illustrated in the segments I excerpted from Dr. Ball's description of the fractions unit, was clearly stated in the introduction to the chapter. According to Dr. Ball, to teach mathematics is to help students develop mathematical understanding and power. To do this,

> ...the teacher must select and construct models, examples, stories, illustrations, and problems that can foster students' mathematical development. (p. 5)

This conception closely matches the vision of mathematics teaching proposed by the National Council of Teachers of Mathematics. Also, as the fractions episode makes clear, it drives Dr. Ball's instructional decision making during both planning and interactive phases of teaching.

Regarding Dr. Ball's knowledge of instructional strategies, the fractions episode provides evidence that she has an extensive repertoire of representations associated with the different meanings of fractions, and that she constructs representational contexts that facilitate her students' explorations of these different meanings. Dr. Ball's detailed discussion of her expectations regarding what her students already knew about fractions, and the multiple sources she used to consider their knowledge (only a few of which were described in the excerpt), illustrate the strength of the third component of her pedagogical content knowledge--knowledge of students' understanding and potential misunderstandings. With respect to the fourth component, Dr. Ball drew upon her knowledge of the state and school district curricula, as well as materials available within the school, to consider the students' prior experiences with fractions and to set objectives for the fractions unit.

This last point illustrates an additional characteristic of Dr. Ball's pedagogical content knowledge--the fact that the four components are highly interconnected in her knowledge system. Thus, she was easily able to draw upon and integrate information from all four components as she thought about how to teach fractions to her third grade students. Also, I would argue, the episode illustrates the uniqueness of pedagogical content knowledge as a knowledge domain. Dr. Ball's knowledge about how to introduce a fractions unit to third grade students was different than a mathematician's knowledge about fractions (content knowledge) and different than an educator's knowledge about general strategies for introducing instructional units (pedagogical knowledge).

Ms. Daniels's Introduction to Volume

This example and the one that follows are taken from the investigation of Learning to Teach Mathematics that I mentioned earlier in the presentation. (For more extensive discussions of that project, and of the two examples, see Borko, Eisenhart, Brown, Underhill, Jones, & Agard, 1992; and Eisenhart, Borko, Underhill, Brown, Jones, & Agard, in press.) In that research program, we followed a small group of novice teachers through their final year of teacher preparation and first year of teaching. Our primary purposes were to describe the participants' knowledge and beliefs relevant to mathematics teaching, their thinking about teaching, their actions in the classroom, and the influences of various personal and contextual factors on this set of professional characteristics. Both examples are taken from our observations of one of the novice teachers, Ms. Daniels (a pseudonym), during her final student teaching placement. They represent different degrees of strength of pedagogical content knowledge.

Ms. Daniels introduced the concept of volume to the Rectangle (above average) group in her sixth grade classroom in a lesson that was part of the regularly scheduled mathematics program. She began the lesson by comparing volume to surface area, explaining that surface area is "the distance around the outside of a three-dimensional figure" or "the distance covering a three-dimensional object." Volume is "the space inside of...a box, a rectangular prism." She then showed the students an empty cardboard box which they identified as a rectangular prism. She explained, "[It's a] rectangular prism. And it just so happens that this rectangular prism is filled with cubes or cubic units." Ms. Daniels held up a small wooden cube and said:

> So, we can call it a cubic unit. Now, what I would like for you to do, I need a volunteer. OK, [Janice], I want you to somehow count how many cubic units cover the volume or the inside of this box. Do that now. Somehow figure it out. If you have to, dump them out and count them.

Ms. Daniels left the students to solve the problem on their own while she worked with the Circle (average) group. She returned on several occasions during the class session to check on their progress and to offer suggestions for how to approach the problem.

On one occasion when Ms. Daniels asked the students how they were doing, they replied that several of them had gotten different numbers when they counted. Ms. Daniels suggested, "Why don't you give ten to each person and see how many tens you've got." The students followed her suggestion.

The next time Ms. Daniels returned to the group, the students had agreed that the correct solution was 90 cubic units. She asked, "OK, now do you think there is an easier way to do this?" She told the students to "see if you can figure out what the pattern is." She then led a discussion in which the students shared their solutions and developed the formula for volume of a rectangular prism. As they explained, they first computed the number of cubes in one layer and then figured out the number of layers. From there, they were able to calculate the number of cubes that the box would hold. Ms. Daniels noted, "That's exactly right. There is a formula for volume. You take the length times the width times the depth or the height is what they call it. L times W times H" She concluded the lesson by writing the formula on the board.

Ms. Daniels's thinking about the lesson. When asked about her planning for the lesson, Ms. Daniels indicated that the original idea to use a box and cubes to illustrate volume came from the students' textbook. However, the book used a two-dimensional representation of a box filled with cubes. The idea to use an actual box and cubes was Ms. Daniels's. She explained,

> [The students] know what the three dimensional shapes are, but they have trouble distinguishing...which one is length, which is width, and which is height....So I think it's better for them to have an actual object for them to look at right in front of them, rather than flat on the paper, especially for volume because...that's on the inside anyway.

Ms. Daniels also considered her expectations for this particular group of students:

> I remember with my classes last placement, the upper level kids are real good at discovering things. And these kids are very upper, upper level, so I thought I'd try it with them to see if it worked.

Ms. Daniels's pedagogical content knowledge. This teaching episode reveals reasonably strong pedagogical content knowledge on the part of Ms. Daniels. She selected an appropriate representation to use as a basis for the group activity. She drew upon her knowledge of students when making the decision to use a concrete example. She used the textbook for ideas; however, she modified its suggestions to better fit characteristics of the students and her objectives for the lesson.

However, Ms. Daniels's pedagogical content knowledge does not appear to be as strong as Dr. Ball's. This assessment is based as much on what she did not say as what she said. For example, Ms. Daniels did not indicate that she considered alternative representations or other problems using the box and cubes representation when planning the lesson. Her reasons for selecting this representation did not appear to be grounded (at least explicitly) in a conception of mathematics teaching. Also, when asked by the interviewer whether the students had been introduced to volume previously, Ms. Daniels responded that she did not think so, revealing a lack of familiarity with the district's K-6 mathematics curriculum.

When reviewing the description of this teaching episode, one of the mathematics educators on our team noticed that Ms. Daniels seemed to jump from the box example to the volume formula very quickly, without explicitly connecting the two. The problem Ms. Daniels posed for her students--finding the volume of a rectangular prism by filling it with cubic units--is one in which the representation leads to the derivation of the formula, rather than just verifying the solution. However, Ms. Daniels did not explicitly help the students to see that connection.

This analysis is not meant as a negative assessment of Ms. Daniels's pedagogical content knowledge or her teaching. On the contrary, the episode represents a reasonably strong mathematics lesson. However, another episode, also in Ms. Daniels's final placement, reveals greater limitations in her pedagogical content knowledge.

The Division of Fractions Episode

My final example is taken from a lesson on division of fractions that occurred during "Morning Math," a time set aside by Ms. Daniels's cooperating teacher for reviewing mathematical skills learned during the year, in preparation for standardized tests that were administered throughout the school division in early May. Ms. Daniels began the lesson by demonstrating and providing a procedural explanation for the division-of-fractions algorithm. Elise, a student in the class, asked, "I was just wondering why, up there when you go and divide it and down there you multiply it, why do you change over?" Ms. Daniels recognized Elise's question as calling for a conceptual explanation, and she attempted to respond by providing a concrete example and accompanying diagram:

> Well, as you learned before, when you divide a fraction into a fraction, the process is to flip the second one and then multiply. And say we have a

> wall, OK, and we divide it into fourths. 1/4 of it is already painted, OK. So we have 3/4 of it left to paint. Right? You agree with me?

Ms. Daniels drew a rectangle on the front board and shaded 1/4 of it.

> But we only have enough paint to paint half of these three fourths. So half of 3/4 would be between about right there. Right, do you agree with that?" Elise replied, "Yes." "There is 1/4 on each side plus half of a fourth. So now if we look at this, this fourth was divided in half, so we divide this fourth in half and this fourth in half. We are left with 1, 2, 3, 4, 5, 6. And if we had this fourth divided in half, it would be what kind of unit. How many units is my wall divided into now? 1, 2, 3, 4, 5, 6, 7, 8. But 2/8 is already covered. We see right here that we have enough paint to cover this many more eighths. Right? When we divide it into eighths, leaving us with how many eighths, 1, 2, 3. OK, oh wait. I did something wrong here.

Ms. Daniels realized that she had made an error. She paused for about 2 minutes, studying the board. She then decided to abandon the attempt to provide a concrete example, saying:

> Well, I am just trying to show you so you can visualize what happens when you divide fractions, but it is kind of hard to see. We'll just use our rule for right now and let me see if I can think of a different way of explaining it to you. OK? But for right now, just invert the second number and then multiply.

For the remainder of the lesson, Ms. Daniels focused on computational procedures for division of fractions and related topics such as converting a mixed number to an improper fraction and visa versa. She demonstrated use of the algorithms and provided guided and independent practice.

Ms. Daniels thinking about the lesson. An analysis of the interviews with Ms. Daniels before and after the lesson reveals that she did not think about representations to use in demonstrating division of fractions when planning the lesson. In fact, she did not plan to provide a conceptual explanation at all. As she explained, "I knew they had already had it [division of fractions] before, so I just figured the main thing was to make sure they remembered to invert and multiply when dividing." Her planning, which was done the morning of the lesson, consisted of selecting a few problems from the appropriate chapter reviews and chapter tests in the text to give to the students to solve.

In discussing the episode with the researcher later that day, Ms. Daniels explained that when faced with Elise's question, "I attempted to do something I had learned about...in the methods course, but it didn't work because I did the wrong thing....The example I had given was multiplication." However, despite her realization that "the explanation...wasn't very good," she was basically pleased with the lesson. As she explained, "I think by the end of the time, that they had picked up on it."

Ms. Daniels's pedagogical content knowledge. This episode is a good illustration of the fuzzy boundary between content knowledge and pedagogical content knowledge. After a great deal of discussion among ourselves, my colleagues on the research project and I concluded that Ms. Daniels's selection of an incorrect application and visual representation indicates limitations in both her content knowledge and pedagogical content knowledge. She did not have a strong conceptual understanding of division of fractions. Therefore, when constructing the representation, she did not realize that she was giving a perfect example of the operator ("of") interpretation of multiplication. Her repertoire of powerful representations clearly was limited (in fact, non-existent). Ms. Daniels's knowledge of students, another component of pedagogical content knowledge, was also limited. She did not realize that her students were likely to have difficulty understanding the conceptual underpinnings of the division-of-fractions algorithm.

The Learning of Pedagogical Content Knowledge

What can we learn about pedagogical content knowledge from these three teaching episodes? The episodes illustrate that there are substantial differences in the pedagogical content knowledge of an expert mathematics teacher like Dr. Ball and a novice like Ms. Daniels (who, by the way, was considered by her cooperating teachers and university supervisors to be a very strong student teacher). Expert teachers, in comparison to novices, have:

1. An overarching conception of what it means to teach a subject matter that is clearer and that they use more systematically as a conceptual map for instructional decision making;
2. A repertoire of instructional strategies that includes a greater number of powerful representations, and the ability to construct representational contexts that better take into account instructional objectives and learner

characteristics;
3. Greater knowledge of what students in their classes know about particular topics and where they are likely to experience difficulty in learning those topics; and
4. More extensive knowledge about the horizontal and vertical curriculum and about curricular materials available to them.

Given these differences between expert and novice teachers, what can be done to help novice teachers strengthen their pedagogical content knowledge? It is not the case that years of experience as a classroom teacher will automatically promote pedagogical content knowledge growth. In fact, in a recent conversation Samuel Wineburg, another of Lee Shulman's former students, commented to me that in some of the work on teacher assessment conducted at Stanford University, second and third year teachers looked stronger in terms of pedagogical content knowledge than did teachers with many more years of classroom experience. One component of pedagogical content knowledge for which this was particularly true was their overarching conception of teaching in their subject areas. The teachers who had more recently completed their teacher preparation programs held conceptions that more closely matched those promoted by current reform efforts. An important question, then, is "What kinds of experiences will promote growth of pedagogical content knowledge?" That is a question many of the presenters and attenders at this conference have been struggling with in our work. And, it is one that the conference, and the ongoing conversations it will hopefully foster, should help us to answer.

It would be remiss of me to conclude this presentation without offering a few of my own thoughts to help stimulate those conversations. The ideas that I will share have been evolving over the years, based on my own work as a teacher educator and my research--both comparing expert and novice teachers and, more recently, studying the process of learning to teach.

I will return to the Learning to Teach Mathematics project, and specifically to the division of fractions episode, to illustrate some of my points. Our analyses of that episode, and the implications we draw for teacher education, are presented in greater detail in an article in the Journal for Research in Mathematics Education (Borko, Eisenhart, Brown, Underhill, Jones & Agard, 1992). In that article we suggest that several personal and situational factors came together to create a situation in which Ms. Daniels did not learn the conceptual information and representations she needed in order to produce an adequate explanation of division of fractions during her teacher preparation program.

One factor that may have been operating to interfere with Ms. Daniels's learning was her own system of knowledge and beliefs. For example, she entered into the final year of her teacher preparation program with the belief that her knowledge base of teaching was strong, or at least adequate to the task of teaching mathematics to elementary and middle school students. This belief probably interfered with her ability to recognize that she did not have the content knowledge and pedagogical content knowledge necessary to implement her beliefs about good teaching for at least some topics in the sixth grade curriculum (e.g., division of fractions). Without this recognition, she may not have put sufficient effort into learning the material presented in the mathematics methods course.

The issue of receptivity to teacher education has been explored by a number of other researchers. For example, Carol Weinstein (1988) found that preservice teachers about to begin student teaching expected teaching tasks to be less problematic for themselves than for others. Dr. Weinstein suggested that preservice teachers may have an unrealistic optimism about their future teaching performance, and that this optimism may be associated with a lack of motivation to become seriously engaged in teacher preparation. Based on these studies, as well as other research on preservice teachers' beliefs about teaching (e.g., Bird, 1991; Hollingsworth, 1989; Holt-Reynolds, 1992), it seems reasonable to conclude that because of their prior beliefs, prospective teachers may not see the relevance of their pedagogy courses to the process of learning to teach, and that they may not attend closely to information or experiences offered by those courses.

Multiple demands placed on Ms. Daniels and the other student teachers by the design of the teacher education program may have also interfered with their learning. These preservice teachers were expected to take responsibility for acquiring the knowledge and skills that were presented in both their university course work and public school classrooms. From the university, they were expected to learn the cognitive and pedagogical skills they would need to be successful teachers. From the public schools, they were expected to learn the culture and norms of the profession. Given the multiple demands they faced, and the fact that they had to student teach for a portion of every school day, they did not have the time to carefully construct and reflect upon their own set of classroom activities and strategies for each lesson they taught. Instead, they had to piece together activities they could use, often the very next day, from ideas they gathered from their university professors and supervisors, cooperating teachers, and peers. In order to meet the requirements they and others set for them, they needed ideas or activities that could be imported, with little modification, into their own classrooms. In other words, they needed "ideas that will work"--techniques that would hold their students' attention while simultaneously providing the necessary subject matter content. As a result, they selectively attended to ideas from the methods course that could be applied directly to their own classrooms, ignoring other aspects (for example, the theoretical aspects) of their course work. This set of priorities and selective attention contributed to a situation in which Ms. Daniels was not likely to work very hard to develop her own conceptual understanding of the division-of-fractions algorithm or to learn strategies for helping students develop similar understandings.

Implications for Teacher Education

Any attempt to reform teacher education will necessarily be multifaceted. It will need to address, in some fashion, each of the factors that influences the process of learning to teach: preservice teachers' knowledge base, the university experience, and the public school experience. It will need to create a system or community in which messages and forces are consistent and are compatible with the vision of teaching being promoted. This presentation, with its focus on the central role of pedagogical content knowledge in teaching, suggests several directions for change.

First, to help prospective teachers think and teach in new ways, university programs must challenge participants' preexisting beliefs about the adequacy of their knowledge base for teaching. These programs must help students to make their implicit beliefs about teaching, learning, subject matter, and learning to teach explicit; challenge the adequacy and consistency of those beliefs; and provide opportunities for students to examine new ideas and integrate new information into their existing belief systems. There is some evidence in the literature that when preservice teacher preparation courses systematically attempt to challenge preservice teachers' beliefs, changes in those beliefs can and do take place (Ball, 1988; Comeaux, 1992; McDiarmid, 1990).

Second, prospective teachers must be given the opportunity in their university course work to strengthen their content knowledge and pedagogical content knowledge. One area of particular difficulty seems to be the development of representations and representational contexts that will enable them to draw connections between concepts and applications, on the one hand, and algorithms and procedures on the other. Teacher preparation programs must provide time and incentives to encourage the kinds of practice and reflection necessary for the development of these components of prospective teachers' professional knowledge base. Instructors must find ways to permit students to talk about and talk through their reasoning and their breakdowns with others who are more proficient and thus can model and assist them. These are issues which many of the projects represented at this conference are addressing.

However, our analyses suggest that it may not be sufficient to simply provide these opportunities for prospective teachers in their university courses. Given the competing demands and pressures they feel, particularly once they begin student teaching, prospective teachers selectively attend to some elements of what they are taught and ignore others. More specifically, "...prospective teachers do not see the relevance of much of what they are taught. Without immediate need for the knowledge, they do not attend to it closely" (McDiarmid, 1990, p. 12). Hence, another implication of this work is that prospective teachers must be placed in student teaching situations that provide the opportunity and support to teach in ways that match the professional community's (and university teacher educators') overarching conception of what it means to teach a particular subject. They must be able to observe experienced teachers model teaching strategies that match this conception of teaching. They must also have time and incentives to prepare lessons that match this conception, receive feedback on their lessons, and be protected from the accountability pressures that potentially restrict their choices.

Such opportunities may necessitate a rethinking of the student teaching experience. For example, planning how to organize and represent content in ways that will facilitate student learning is an extremely time-consuming task for novice teachers, whose pedagogical content knowledge is not well-developed (Livingston & Borko, 1989). The demands created by student teaching full time, or even part time on a daily basis, may not permit the time they need to carefully plan and systematically reflect on lessons.

Student teaching placement decisions are also crucial. Cooperating teachers, in addition to teaching in ways that exemplify the profession's overarching conception, must provide support, guidance, and feedback to student teachers. In other words, they must be teacher educators as well as teachers. However, even outstanding teachers do not always have the expertise (or the inclination) to be teacher educators (Berliner, 1989). Cooperating teachers must be carefully selected on the basis of their motivation and skills as teacher educators as well as their pedagogical expertise.

As I am sure all of you will agree, to accomplish changes in any one of these areas is not a trivial task. And the task is made more complex by the need for simultaneous, coordinated changes in the university and public school components of teacher education programs. However, with the careful thinking and hard work represented by the projects featured at this conference, as well as reform efforts in which many other conference attenders are involved, I am optimistic that we are on the road to making significant improvements in our efforts to help novice teachers develop and strengthen the knowledge that is unique to the profession of teaching--their pedagogical content knowledge.

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PROJECT SUMMARIES

QUALITY UNIVERSITY ELEMENTARY SCIENCE TEACHING PROJECT (Q.U.E.S.T.)

Dorothy Gabel
Indiana University

THE DEVELOPMENT OF AN INNOVATIVE MODEL FOR THE PRE-SERVICE PREPARATION OF ELEMENTARY TEACHERS

Emmett Wright
Kansas State University

PROJECT STEP (SCIENCE TEACHER EDUCATION PROGRAM)

James J. Copi
Madonna University

MATHEMATICS AND TEACHING THROUGH HYPERMEDIA (M.A.T.H.)

Deborah Ball and Magdalene Lampert
Michigan State University

AN INTEGRATED SCIENCE SEQUENCE FOR ELEMENTARY EDUCATION MAJORS

Sandra Harpole
Mississippi State University

TEACHING STUDENTS MEANINGFUL THINKING STRATEGIES IN BIOLOGY

Kathleen M. Fisher
San Diego State University

A MODEL PROGRAM IN SCIENCE AND MATHEMATICS FOR ELEMENTARY PRE-SERVICE TEACHERS

Henry Heikkinen and Teresa McDevitt
University of Northern Colorado

PREPARATION OF ELEMENTARY MATHEMATICS AND SCIENCE TEACHERS (PEMST)

Jack Wilkinson and Robert Ward
University of Northern Iowa

AN EXPERIMENTAL TEACHER EDUCATION PROGRAM IN ELEMENTARY SCIENCE

Patricia McClurg and Joe Stephans
University of Wyoming

BRIDGING THE GAP BETWEEN THEORY AND PRACTICE IN THE TEACHING OF ELEMENTARY SCHOOL MATHEMATICS

Elizabeth Goldman and Horace Williams
Vanderbilt University

IMPROVING SCIENCE EDUCATION: A COLLABORATIVE APPROACH TO THE PREPARATION OF ELEMENTARY SCHOOL TEACHERS

Melvin Joesten and Elizabeth Goldman
Vanderbilt University

QUALITY UNIVERSITY ELEMENTARY SCIENCE TEACHING (Q.U.E.S.T.)

Dorothy Gabel
Indiana University

In response to the national concern about the quality of science teaching at the elementary level, Indiana University has created an excellent program for preparing prospective teachers to become leaders in their schools in the teaching of science.

The program has two facets: (1) the improvement of the science program for all prospective elementary teachers, and (2) the creation of a special program for students selecting the science area of concentration (18 additional hours of science, total 30 hours).

Resources from the National Science Foundation for the four year funded period will be used to create a model program that includes the following activities:

1. Modification of three of four existing science courses (Basic Science Skills, Biology, and Physical Science) to include a greater emphasis on conceptual understanding of science content, increased use of an inquiry approach and the use of technology in data collection and processing.
2. Development of three new interactive computer-assisted-instruction modules on basic science skills to complement those now being used in the Basic Science Skills course.
3. Development of a new four credit-hour, interdisciplinary, capstone science course that will be jointly taught by faculty from biology, geology, chemistry, physics, and astronomy that will be required for prospective elementary teachers with a science concentration.
4. Modification of the existing elementary science methods course to include an increased emphasis on technological applications.
5. Development of a new elementary science methods courses that will be integrated with the capstone science courses for preservice teachers with the science concentration.
6. Preparation of a cadre of elementary teachers at the local schools who will serve as mentors during the student teaching experience.

7. Establishment of a Saturday Science Experience Program for elementary-aged children in the surrounding area that will provide observation and small group teaching experiences for preservice and inservice teachers.

8. Building cooperative relationships among scientists, science educators, and educational psychologists in designing, implementing, and evaluating the program.

9. Evaluating the effectiveness of specific components of the program including the Saturday Science School, the capstone interdisciplinary course, the newly developed interactive computer assisted instruction modules, the mentor teacher component, and the student teaching experience.

The aspects of this project highlighted at the conference are listed below.

Development of the physical science course:	Cathy Olmer, Panel 1
School and university collaboration:	Karen Stucky, Panel 6
University faculty development:	Dorothy Gabel, Panel 7

THE DEVELOPMENT OF AN INNOVATIVE MODEL FOR THE PRE-SERVICE PREPARATION OF ELEMENTARY TEACHERS

Emmett Wright
Kansas State University

During the fall 1990 Kansas State University (KSU) began a major university-wide project to develop, field test, revise, institutionalize, and disseminate a model research-based preservice training program to prepare elementary teachers for science, mathematics, and technology teaching. Four key premises underlie the program. Elementary teachers need to be prepared: (a) Through an articulated, unified program collaboratively developed by content specialists, education specialists, and school practitioners; (b) with a broad and solid foundation in science, mathematics and technological content; (c) in rigorous and effective methods of teaching science, mathematics, and technology based of innovative practice and current research; and (d) through extensive field experiences in diversified school settings with mathematics, science, and technology teaching.

A major focus of the project is the creation of a partnership between the College of Arts and Sciences, the College of Education, and the local public schools according to guidelines established by the Holmes Group (1989). All Project participants are committed to the vision that teacher preparation must be a joint responsibility involving these diverse groups of professionals.

Project teams have been identified to include content specialists (scientists and mathematicians), education specialists (science, mathematics and technology educators, and curriculum and instruction generalists), and school system practitioners (teachers and administrators). Through collaborative planning seminars, the project team is responsible for determining program requirements and developing preservice courses and clinical field experiences. Team members will assist throughout with the field testing, revision, and dissemination of the model program.

At this date the project team has been divided into four planning teams which are meeting on a bimonthly basis for collaborative planning seminars. We have a mathematics team, a physical science team, a life science team and an interdisciplinary team. Each team has several KSU faculty from a science department (Biology, Chemistry, Geology, or Physics), and/or the Mathematics

Department, the College of Education, several teachers, a building principal, and/or a district administrator and a graduate student. Undergraduates who began the project this fall 1991, will also be represented on each team.

The collaborative planning seminars provide the time and opportunity for the project team to study and select the best theories, instructional methods, and materials for courses and field experiences to prepare elementary teachers. The intensive communication and collaboration will result in a more unified and integrated preparation program.

Through the process of collaborative planning we will develop thirty-five semester hours of science and mathematics courses specifically designed for elementary teachers, six semester hours of instructional methodology integrated and taught in conjunction with the content courses, and three years of extensive field experiences in school settings to be coordinated with content and methodology courses.

Three professional development schools have been created as an outcome of this collaborative effort. Twenty-five teachers have been selected as master cooperating teachers and three as clinical instructors to function as supervisors of the field experiences, co-developers of the model program, and co-teachers of university courses. The professional development schools and the partnerships between the colleges of Education, and Arts and Sciences, and the public schools will become a model for KSU's entire teacher preparation program at the conclusion of the project.

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The aspects of this project highlighted at the conference are listed below.

Development of the mathematics course:	Bill Parker, Panel 1
Development of the physics course:	Dean Zollman, Panel 1
Program development:	Gail Shroyer, Panel 3
Use of interactive videodisc in the physics course:	Dean Zollman, Panel 5
Establishing professional development schools:	Gail Shroyer & Nancy Thompson, Panel 6
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PROJECT STEP (SCIENCE TEACHER EDUCATION PROGRAM)

James J. Copi
Madonna University

Project STEP is an initiative funded for five years by the National Science Foundation (NSF) and Madonna University to develop preservice students into proficient elementary and middle school science teachers. Students major in General Science and obtain an Elementary Education Teaching Certificate.

Science lab activities have been revised to provide college-level instruction using techniques that can be easily modified for the elementary classroom. The materials are inexpensive (paper cups, coffee filters, toothpicks, clay, etc.) and the experiments are fun (counting how many M & Ms you have of each color, calculating their ratios and snacking on the M&Ms when done). Such activities involve six science courses involving two semesters each of biology, chemistry and physics.

Seven education courses are being modularized to blend science, technology and society (STS) concepts. These changes will not only benefit the general science education students, but they will also benefit other content majors who are part of the education-planned program.

Current efforts have concentrated upon: student recruitment and retention; meetings with the Science Project Advisory and Support team including Madonna University science and education faculty, science specialists, school administrators, and community leaders; increased collaboration between science and education faculty at Madonna University; faculty workshops dealing with how students learn and improving sensitization to the needs of minority students; seeking advice from consultants; visitations of our external evaluators (Drs. Robert and Bernadine Stake, CIRCE, University of Illinois-Champaign).

The Project STEP Summer Vestibule Program is scheduled during the last two weeks in June, just as summer recess begins and just before summer vacations start. Potential students select five sessions of four hours duration each to fit their schedules (sessions are held mornings in one week and evenings in the other). Participants are exposed to the campus environment, staff, faculty, and each other. The schedule is fast-paced to include a series of short campus tours, hands-on lab activities, a field trip, guest speakers, help with filing out forms (financial aid, admissions, registration, etc.), computer lab activities, academic readiness testing, a review of the course requirements, and success sessions (college survival skills).

Future endeavors will focus upon field placements in elementary science classrooms that have minority enrollments, ideally with master science teachers. The developed science education model will be distributed to liberal arts institutions with enrollments similar to Madonna University's and who have an elementary teacher preparation program. A dissemination booklet will be prepared near the end of the project which will include an overview of the program and a description of its philosophy, recruitment procedures, course syllabi, evaluation techniques and collaborative relations.

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Jim Copi describes his project in more detail in Panel 4.
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MATHEMATICS AND TEACHING THROUGH HYPERMEDIA (M.A.T.H.)

Deborah Ball and Magdalene Lampert
Michigan State University

Mathematics and Teaching through Hypermedia (M.A.T.H.) is a research and development project that aims to explore the use of new technologies to create tools for use in elementary teacher preparation as well as in research on teaching. We are producing a new learning environment for teacher education by linking video images of exemplary mathematics teaching with analyses of lessons that examine both pedagogy and mathematical content. Videotapes of lessons have been recorded across a year's instruction in a third and a fifth grade class during 1989-90. The mathematics teachers in these classes (Ball and Lampert) are not typical; their teaching is grounded in a disciplinary perspective on mathematics and grows out of current thinking about what ought to be occurring in mathematics education. They also have a greater capacity than full time teachers to stand back from their practice and analyze it with observers. At the same time, their teaching is enacted on a daily basis in ordinary classrooms with a wide range and diversity of students. In addition to videos of lessons, we have been collecting video, audio and written accounts of the teachers' reflections on what they did; and video, audio and written commentaries on the lessons prepared by students in the classes, mathematicians, school-based collaborators, teacher educators, and educational researchers. These "annotations" will be attached to the lessons in a hypermedia computer system in order to support random and flexible access to cases and analyses from multiple perspectives. Students and instructors will also be able to construct their own analyses.

Underlying the design of this project is the idea that knowledge about teaching is constructed in particular settings in which teaching and learning occurs, and that this knowledge can be made directly available to practitioners and researchers who want to learn about teaching. The tools designed are intended to help users inquire into teaching and learning, pursuing questions and conjectures, and engage in conversations with others interested in dilemmas of teaching mathematics. The technology offers rapidly-increasing possibilities to learn to represent construction and use of knowledge in practice. In addition to challenging assumptions about what and how children learn about mathematics in school, as well as about who learns mathematics, the materials will provide a terrain for discussions about what is worth knowing and why, and about alternative pedagogical practices and choices. We expect the materials we are producing to have an impact on the way teacher education is structured in the university setting and we expect to learn about the potential of new kinds of information, presented using new kinds of media, to change the way prospective teachers and teacher educators think about mathematics teaching.

Deborah Ball describes this project in more detail in Panel 5.

AN INTEGRATED SCIENCE SEQUENCE FOR ELEMENTARY EDUCATION MAJORS

Sandra H. Harpole
Mississippi State University

The five-year project focuses on the development and implementation of a three-semester sequence of courses to provide preservice teachers with a solid content while preparing them to teach hands-on science in the elementary school. Content areas include physics, astronomy, chemistry, geology and biology. Special laboratory sections will focus on the application of content, use of guided-discovery teaching methods, and the development of process skills. The core curriculum of elementary education majors beginning with incoming freshmen of 1991 will include these three courses and accompanying laboratories.

Arts and Sciences faculty involved in developing and teaching the courses have attended a series of seminars and workshops exposing them to current science education research, methods of teaching by guided discovery, and newly developed curriculum materials for the elementary and middle school student in preparation for the development of course and laboratory materials during the summer of 1991. Four outstanding Mississippi elementary school teachers served as consultants during the 1991 summer workshops.

Preservice teachers, upon completion of the three-course sequence, will apply content knowledge and laboratory skills to the elementary education science methods class by planning lessons with increased science content and will translate laboratory activities into activities that are meaningful and appropriate for children. As student teachers, students will be placed with teachers trained in a three-week workshop to serve as mentors to insure that students are exposed to good science teaching and given the opportunity and encouragement to teach science as they have been taught. Students will be evaluated during student teaching and their first year of teaching.

The aspects of this project highlighted at the conference are listed below.

Program development:	Sandra Harpole, Panel 3
Establishing administrative support for the project:	Terry Crow, Panel 8

TEACHING STUDENTS MEANINGFUL THINKING STRATEGIES IN BIOLOGY

Kathleen M. Fisher
San Diego State University

This summary reports the first of a series of classroom studies with students in a hands-on biology course for prospective teachers (upper division Liberal Options majors). Course goals include helping students to 1) overcome science anxiety; 2) enjoy science; and 3) acquire confidence in teaching science as well as to model hands-on science teaching strategies for students. Another course goal is to change students' habits of the mind, shifting them away from deeply ingrained rote learning styles and toward meaningful, integrated, conceptual learning.

A Macintosh-based tool, SemNet^{TM}, was used to promote shifts in learning styles. SemNet is a general purpose tool with which a user can construct a knowledge representation in the form of a semantic network--that is, a network of concepts linked by named relations, with associated texts and images. The semantic network essentially provides a map of the cognitive terrain that surrounds and gives meaning to a concept.

The course is taught in two interconnected classrooms, one a wet laboratory and the other equipped with nearly 30 computer stations, primarily Macintosh IIcx computers. Each course section meets twice a week for 2.5 hours each. The compute lab is open about 20 hours per week outside of class. Students work in collaborative groups to perform and analyze simple experiments. The theme of the course is "Characteristics of Living Things."

The study involved 56 students in two course sections. Students initially were largely computer naive and weak in biology knowledge (in spite of having taken at learn two previous biology courses). The following survey instruments were administered before and after instruction: knowledge tests, Schmeck's Inventory of Learning Processes, computer and biology anxiety scales, an attitude survey and a demographic survey. Students also completed the Meyers-Briggs survey and ten weekly journals. Student assignments included constructing three semantic networks to summarize their learning. Two of their three midterms and their final exam also included generation of semantic networks. Many students pasted a semantic network into a concept map as an extra credit project.

Incorporating a sophisticated learning tool into a classroom is a challenging undertaking that requires significant curriculum development. Learning to use the computer and software involved a progression from fear and skepticism to frustration to success and satisfaction. Many students also experienced difficulty with various subskills required for constructing knowledge representation. We have since developed curriculum materials to help students acquire many of the needed skills.

Most of our students work outside class with approximately half working more than 20 hours per week. On the Meyers-Briggs scale, there were slightly more sensing and extroverted types than intuitive and introverted types among prospective elementary school teachers as compared to the general population.

Students made significant gains in biology knowledge during the semester. They also increased significantly on the deep processing and elaborative processing scales of Schmeck's Inventory of Learning Processes but not on the methodical student or fact retention scales. This Inventory is a self-report scale, and it is possible that student attitudes toward learning changed (resulting in significant shifts) but that their actual thinking patterns did not.

For this reason on their final exam students were presented with a condensed *Scientific American* article and asked to represent it in a semantic network. When they were done all notes, papers, and nets were collected, and students were asked to summarize the paper from memory. Their summaries were impressively coherent and complete, suggesting that they were actually assimilating the information in an organized fashion.

Three predictions which we will be testing in future studies are that constructing a semantic network about a topic will increase a student's ability to 1) write an extemporaneous paper or 2) give an extemporaneous talk about that topic, or 3) solve a problem that requires knowledge of the topic. The final exam described above is the first step in testing the first prediction.

Students generally found the computing exercises to be a valuable addition to the course. Many students with poor learning skills appeared to make significant progress and some were genuinely excited by their insights.

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Kathleen Fisher describes her project in more detail in Panel 5.
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A MODEL PROGRAM IN SCIENCE AND MATHEMATICS FOR ELEMENTARY PRE-SERVICE TEACHERS

Henry Heikkinen and Teresa McDevitt
University of Northern Colorado

This five-year project is involved in developing and evaluating a model approach to preparing prospective elementary teachers in mathematics and science. The focus is on building integrated knowledge in mathematics and science, developing effective teaching skills, and cultivating self-confidence and positive attitudes towards these subjects. Integration of all preservice components--content courses, methods of teaching courses, education courses, and early, sustained field experiences--is a project priority. Nine undergraduate content and methods courses are being re-designed or created as part of this comprehensive project, as well as special enrichment materials in other professional teacher education courses.

Project instructional materials address the special behaviors and skills (problem solving, modeling, "hands-on" activities) needed for effective teaching of elementary science and mathematics. Attention is given to special instructional strategies (laboratory work, discussions, cooperative learning groups, and visual-spatial activities) particularly appropriate for groups presently underrepresented in scientific and technological fields (women, minorities, handicapped). It is anticipated that the resulting model program will be widely disseminated due to the modular nature of many of the materials and the contemporary themes of content integration, equity, and active student engagement that project materials address.

Project efforts are greatly enhanced by the presence of full-time, experienced elementary teachers (called mentor teachers) who work in a team capacity with senior project staff in all phases of course design, delivery, and revision.

The College of Education and the College of Arts and Sciences are dedicated to joint efforts to improve teacher education. The cooperative development and implementation of this project as well as considerable college and university project support attest to the centrality of teacher education at UNC. We welcome inquiries regarding our project efforts, and are prepared to share project experiences and materials (when available) with other interested institutions.

The aspects of this project highlighted at the conference are listed below.

Development of the earth science course:	Jay Hackett & Kathryn Cochran, Panel 1
Development of the mathematics courses:	Chuck McNerney, Panel 1
Development of the educational psychology course:	Jeanne Ormrod & Kathryn Cochran, Panel 2
Development of the mathematics methods course:	Rick Silverman, Panel 2
Development of a course on equity issues:	April Gardner & Mike Fitzgerald, Panel 4
Mentor teachers impact on the project:	Bj Stone, Panel 6
University faculty development:	Teresa McDevitt & Ivo Lindauer, Panel 7
Administrative support for the project:	Carolyn Cody, Panel 8

THE PREPARATION OF ELEMENTARY MATHEMATICS AND SCIENCE TEACHER PROJECT (PEMST PROJECT)

Robert Ward
University of Northern Iowa

The Preparation of Elementary Mathematics and Science Teacher (PEMST) Project is developing improved programs for students majoring in elementary education who wish to minor in mathematics or in science. At present there are about 150 mathematics minors and 60 science minors out of 1300 elementary education majors at UNI. The Project was begun in 1988 with funding from the Teacher Preparation Program of the National Science Foundation. This funding will conclude in 1993. The Project is administered by two co-directors and a Steering Committee of six faculty members. Representatives from the mathematics and science departments in the College of Natural Sciences and from the Department of Curriculum and Instruction in the College of Education comprise the committee. There is also an Advisory Board with three national experts, two persons from the Iowa Department of Education, and four local teachers and administrators.

The Project has three components. The initial focus was on the development of new courses and the revision of some existing ones to serve the 26 semester hour science minor and the 25 semester hour mathematics minor. In the science area, two introductory courses for elementary education majors already existed which fulfilled general education requirements. The PEMST Project has developed three new intermediate level science courses which consider pedagogical as well as content issues. One methods course was revised and another new course with a strong field experience component was developed as the culminating course in the program.

In mathematics there was a more extensive program already in place prior to the Project, but it was felt extensive revisions were desirable. This was partly to respond to the NCTM Standards. Six new courses have been developed and three others extensively revised. The course development work in both mathematics and science is nearly completed, with most new or revised courses in their second or third tryout.

The second component of the project was directed at improving the student teaching experience for minors in mathematics and in science. Our students do their student teaching at one of ten UNI student teaching centers distributed around Iowa. Over the last two summers we have worked with about 100 elementary teachers from these centers, both to make them familiar with the expectations we have for our student teachers and to give them new ideas about teaching mathematics and science in their classrooms. Our plan is that each of the minors in mathematics or in science will do at least half of his or her student teaching with one of the teachers with whom we have worked. Our work with the teachers is for three weeks, spread over two summers. About 60 of the cooperating teachers still have their final summer workshop to complete in 1992, but already this aspect of the Project has been very beneficial, both to the student teaching component of the two minor programs and to the schools involved.

The third component of the PEMST Project is to support our graduates during their induction year into teaching. Although we feel that this is a vital part of the preparation of teachers, we are very unclear about how this can best be done. Last summer we conducted a two day workshop for teachers who wished to learn more about being a mentor to a new teacher. We invited those teachers who had completed our workshop for cooperating teachers, as described above. Some of them are serving this year as mentors for our graduates who took positions in their school districts, but this only serves a small fraction of our recent graduates. However, we feel it will help us better understand the problems and needs of our graduates in their first year of teaching. We also are looking at other ways we can offer support to our recent graduates, even when the contact is more limited.

Our evaluation program is designed both to collect information useful in the continued improvement of the various components of the project and to asses the overall effectiveness of the minor programs. We are using several instruments to measure changes in the students' attitudes toward science and mathematics and attitude toward the teaching of science and mathematics. Some comparison is being made to elementary education majors in other minors. Exit interviews of a sample of our students have been very useful in identifying problems and weaknesses in the programs. Some similar evaluations have also been done on the workshops for cooperating teachers. During the next two years we plan to gather information on the attitude and performance of our graduates while they are in their first or second year of teaching.

The aspects of this project highlighted at the conference are listed below.

Development of the science methods course:	Cherin Lee, Panel 2
Development of math and science minor programs:	Jack Wilkinson, Panel 3
Science learning for physically disabled children:	Greg Stefanich, Panel 4
Summer workshops for cooperating teachers:	Jack Wilkinson, Panel 6
University mathematics faculty development:	Dianne Thiessen, Panel 7

AN EXPERIMENTAL TEACHER EDUCATION PROGRAM IN ELEMENTARY SCIENCE

Pat McClurg, Joe Stepans, and Ronald Beiswenger
University of Wyoming

This project is intended to develop and field test a new program for the preparation of elementary teachers in appropriate science content and the most effective science teaching methods currently available. The experimental program will focus on prospective teachers' understanding of science, their confidence in teaching science, their level of concern, and their attitude toward science. The program will employ cooperative learning strategies, coaching and feedback, student-teaching with mentor teachers committed to teaching science, training in the use of a learning cycle approach to science teaching, a blended approach to science content and teaching methods and exposure to positive attitude-enhancing experiences with the profession of science.

Three major program components were developed:

1. Science Content
An earth science course, a physical science course, and a life science course will be designed, tested, and revised by a team of scientists and science educators.

2. Teaching Strategies and Techniques
Seminars, designed to provide explicit connections between science content and teaching in the elementary school, will be developed and conducted concurrently with each of the three content courses. A methods course, emphasizing effective science teaching strategies, will be developed, tested, and revised. This course will follow the content/seminar sequence.

3. Experiences with Professionals in the Field
Collaborative training sessions will be held with area teachers. These teachers will serve as mentors to students doing practicum work during their methods class and during student teaching.

Intended outcomes of the project include:

1. Development and long-term implementation of an effective model program for preparation of elementary teachers to teach science.
2. Training and long-term use of a cadre of trained mentor teachers to help prepare future generations of elementary teachers.
3. Research data regarding the degree of transfer of strategies learned in a teacher preparation program to actual classroom teaching by program participants.
4. Overall improvement of science instruction for area elementary school children.
5. Dissemination of the model program to teacher training institutions throughout the nation.

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The aspects of this project highlighted at the conference are listed below.

Development of the science courses:	Ron Beiswenger, Panel 1
Education seminars and science methods course:	Joe Stepans, Panel 2
Program development:	Pat McClurg, Panel 3
Mentor teacher activities in the project:	Pat McClurg, Panel 6
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BRIDGING THE GAP BETWEEN THEORY AND PRACTICE IN THE TEACHING OF ELEMENTARY SCHOOL MATHEMATICS

Elizabeth Goldman and Horace Williams
Vanderbilt University

The goal of the project is to improve the mathematics content/methods component of the elementary teacher education program. The project uses fifteen "consultant" teachers from grades 4-6 in area schools to assist with the preparation of videodisc and curricular materials designed to provide classroom examples of learning and instructional theory and mathematical concepts. Selection of content for the discs is based upon recommendations from NCTM Standards, research on the teaching and learning of mathematics, and recommendations from project staff, advisory committee members, and consulting teachers. Each disc is organized around some theme (e.g., expert-novice contrasts in mathematics teaching) or content topic (such as teaching fractions or teaching subtraction), and the discs are controlled by HyperCard programs on Apple Macintosh computers. The random-access capability of the videodisc allows video segments to be retrieved for analysis, illustration, or contrast, and HyperCard allows the video to be integrated with other forms of information such as text, audio, and computer graphics.

The prototype materials are being used in methods classes at Vanderbilt to provide structured experiences in analyzing aspects of elementary-level mathematics lessons. The instructor may use part of a HyperCard stack and related videodisc segments to illustrate points in a lecture or to lead discussion of issues such as a child's interpretation of a geometry task, a teacher's response to a child's misconception, or a teacher's choice of representation or materials. Some of the class sessions are conducted in the computer lab, and materials are available to students during lab hours for additional study. Significant differences in field-placement teaching performance favored students who had enrolled in the revised methods course, and student response has been positive.

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Elizabeth Goldman describes this project in more detail in Panel 5.
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IMPROVING SCIENCE EDUCATION: A COLLABORATIVE APPROACH TO THE PREPARATION OF ELEMENTARY SCHOOL TEACHERS

Melvin Joesten and Elizabeth Goldman
Vanderbilt University

The main goals of the project are to improve basic science instruction for undergraduates and to provide models of effective teaching for prospective teachers. Basic science courses offered in the College of Arts and Sciences have been revised and University certification requirements have been changed to ensure a common science background for prospective elementary teachers entering the science methods course. Majors in Natural Science and Science/Mathematics Studies have been designed and are approved to meet new Tennessee elementary certification requirements for a teaching content major.

The science methods course is being revised to build upon the basic science courses, and videodiscs with associated HyperCard programs are being developed for use in the methods course. Through this medium, prospective teachers are able to see and analyze actual classroom examples of the kinds of instruction that have been demonstrated to be effective in helping children develop the skills of inquiry, discovery, and problem solving. Fifteen elementary and middle school science teachers from the local schools are participating in a series of professional seminars and workshops with Vanderbilt faculty, and these teachers are advising and serving as models for videotaped lessons that will be used on the discs. As institutions of higher education and the schools develop a closer working relationship and formulate common goals for the education of new teachers, elementary teachers should be better prepared to teach science in a way that is scientifically and pedagogically appropriate and practical for the real world of the classroom.

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Elizabeth Goldman describes this project in more detail in Panel 5.
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TEACHER KNOWLEDGE ISSUES

PANEL SESSION 1:
Developing Teachers' Mathematics and Science Content Knowledge

DEVELOPMENT OF THREE SCIENCE CONTENT COURSES FOR ELEMENTARY EDUCATION MAJORS AT THE UNIVERSITY OF WYOMING

Ronald E. Beiswenger
University of Wyoming

EARTH SCIENCE CONCEPTS FOR ELEMENTARY TEACHERS

Jay Hackett and Kathryn F. Cochran
University of Northern Colorado

DEVELOPING TEACHERS' MATHEMATICS AND SCIENCE CONTENT KNOWLEDGE: MATHEMATICS KNOWLEDGE

Chuck McNerney
University of Northern Colorado

LEARNING CYCLES FOR A LARGE-ENROLLMENT CLASS

Dean Zollman
Kansas State University

PHYSICAL SCIENCE FOR ELEMENTARY EDUCATION MAJORS AT INDIANA UNIVERSITY

Catherine Olmer
Indiana University

DEVELOPMENT OF THREE SCIENCE CONTENT COURSES FOR ELEMENTARY EDUCATION MAJORS AT THE UNIVERSITY OF WYOMING

Ronald E. Beiswenger
The University of Wyoming

Rationale and Objectives

The University of Wyoming's Experimental Teacher Education Program in Elementary Science is an effort to improve the education of prospective elementary teachers in the area of science. The project is in its fourth year and has been funded by a grant from the National Science Foundation (NSF).

We decided to focus on the elementary level because it is well known that children begin school as curious, natural scientists, but by the time they reach third grade half of them don't like science. At least part of this is because undergraduate elementary education majors typically are not well-educated in science and many of them are afraid of taking science courses. Consequently, when they become elementary teachers they often neglect the teaching of science, or they teach it from a textbook with very little emphasis on laboratory activities (National Science Board, 1983; Task Force on Science Education for Economic Development, 1983; Feistritzer and Boyer, 1983). As stated by McClurg in another paper in these proceedings, the goal of the program is to produce teachers who:

1. are confident in their ability to do science;
2. are knowledgeable
   who have a solid foundation in science content;
   who have a realistic view of science and technology;
   who are competent in designing and implementing
   effective science instruction;
3. are excited about teaching science; and
4. exhibit a positive attitude toward science.

The program has three major components.

1. There are three content courses--earth science, physical science and life science. Every elementary education major is required to take all three and each of the courses includes a laboratory.
2. The program includes a methods course and educational seminars that are taught in association with each of the content courses.
3. A third component involves teaching experiences with mentors (exemplary elementary teachers who are specifically trained to work with the students in our program).

This paper discusses the three content courses. Other program components are described elsewhere in these proceedings. The courses are designed to be as interesting and as motivating as possible with a strong emphasis on the importance of science in our everyday lives. There has also been a strong commitment to make them rigorous, college-level science courses, not watered down science. Outlines for the courses are given in Tables 1-3. Because each teacher education program is unique it would be surprising if these courses could be adopted without modification for use in other programs. However, these courses can be viewed as models if the focus is broadened to include the process of course development as well as the specific content of the courses.

Approaches

Course development. The courses were developed by teams of university faculty drawn from the sciences and science education (see Table 4). NSF funding was used to obtain release time (25%) for the members of the teams so that they could meet on a regular basis for one semester to develop the courses. NSF required the university to support the teaching of the courses. The courses were developed, taught during the subsequent semester, revised and then taught a second time. In each case, the course developers also taught the courses.

The process of selecting the teams began with a meeting of the deans of the Education and the Arts and Sciences Colleges, and the science department heads. Once these administrators expressed support for the program, interested faculty either volunteered or were invited to join course development teams. The three courses were developed in sequence over three semesters so that only one course development team was meeting at a time.

Table 1

Outline for the earth science course

THE EARTH: ITS PHYSICAL ENVIRONMENT

I. Our scientific heritage
  A. Fundamental questions
  B. Size and shape of the earth
  C. Time and seasons
  D. Solar System models
  E. Maps
  F. Remote sensing
  G. Playfair's Law
  H. Modeling the interior of the earth

II. Plate tectonics
  A. Patterns
  B. Whiplash
  C. Rocks and minerals
  D. Planetary geology

III. Atmospheric perturbations
  A. Global climate
    1. General aspects
    2. Sun angle
    3. Continental position
    4. Factors affecting climate
    5. Atmospheric pressure and winds
    6. Specific causes of climate
  B. Weather
    1. Weather maps
    2. Dew point/humidity
    3. Fronts
    4. North American weather
    5. Air masses
    6. Predicting weather

IV. Energy resources and modern society
  A. Dilemma: acid rain and a proposed steel mill
  B. Origin of the atmosphere
  C. Origin of coal and oil
  D. Burning of fossil fuels
  E. Exponential growth
  F. Acid rain lab
  G. Coal lab
  H. Soils and acidity

Table 2
Outline for the physical science course

FUNDAMENTALS OF THE PHYSICAL UNIVERSE

I. Properties of matter
  A. Description of matter
  B. Solutions, compounds and mixtures
  C. Principle of definite composition
  D. Atoms, electrons, protons and neutrons
  E. Acids and bases

II. Energy
  A. Forms of energy
  B. Heat, chemical reactions and heat systems
  C. Conversions of energy
  D. Energy changes in the chemistry of life

III. Electricity
  A. Current and circuits
  B. Electricity in everyday life
  C. Electromagnetic interactions

IV. Waves and light
  A. Waves on a string
  B. Water waves
  C. Sound
  D. Light and the electromagnetic spectrum
  E. Light as a ray--mirrors and lenses
  F. Diffraction and interference

Table 3
Outline for the life science course

LIFE SCIENCE

I. Science and pseudo science

II. Overpopulation, over consumption and their consequences.
   A. Global ecology
   B. Natural resources
   C. Ecosystems
   D. Sustainability

III. Biodiversity
   A. Kingdoms of life
   B. Producers and decomposers
   C. Photosynthesis
   D. Geography of the producers
   E. Insects
   F. Change through time
   G. Speciation

IV. Wellness and disease
   A. Human mortality and morbidity
   B. Infectious disease
   C. Digestion
   D. Nutrition
   E. Chemical respiration and circulation
   F. Excretion and ventilation

V. Biotechnology
   A. Cells
      1. Atoms, molecules and life
      2. The dynamic cell
   B. Cell division
   C. Mendelian genetics
   D. How genes work
   E. Genetic counseling

Table 4

College/departmental affiliations of the course development teams

Earth Science Course

- College of Arts and Sciences:
  - Department of Geography and Recreation
  - Department of Geology and Geophysics
  - Department of Physics and Astronomy
- College of Education:
  - Division of Lifelong Learning and Instruction
- College of Engineering:
  - Department of Atmospheric Science

Physical Science Course

- College of Arts and Sciences:
  - Department of Chemistry
  - Department of Physics and Astronomy
- College of Education:
  - Division of Lifelong Learning and Instruction
- Wyoming Institute for the Development of Teaching and Learning (jointly administered by the Colleges of Arts and Sciences and Education)

Life Science Course

- College of Arts and Sciences:
  - Department of Botany
  - Department of Zoology and Physiology
- College of Education:
  - Division of Lifelong Learning and Instruction
- College of Agriculture:
  - Department of Animal Science
  - Department of Plant, Soil and Insect Sciences

The teams were diverse, collectively representing four colleges and eleven departments. Consequently, the initial meetings of the teams were brainstorming sessions that enabled team members to get to know each other and to reach consensus on an overall course philosophy. Once effective communication was established, the teams created course outlines. To facilitate discussion, individual team members volunteered to develop draft outlines for the various sections of the course. The outlines were discussed and revised during subsequent team meetings. Finally, an overall course outline was assembled. The teams also developed original learning materials, selected textbooks, developed a time schedule for the course, located laboratory teaching space and produced detailed course syllabi.

Teaching the courses. When the courses were taught, members of the course development teams served as leaders for the various sections of the courses. These leaders taught the largest share of their sections and coordinated the involvement of other faculty in teaching other topics. At least two instructors at a time (including the Graduate Teaching Assistant) were in the classroom and for some activities, all team members were present. A member of the project staff observed the class sessions to monitor (but not evaluate) course activities. This enabled the project staff to more effectively integrate seminar activities with the material presented in the content courses. Occasionally, the staff observer was asked to provide informal feedback to the content instructors concerning the appropriateness of content and pedagogy.

Revising the courses. After the courses were taught for the first time the course development teams met again to revise them. This involved a series of meetings during one semester. Revisions were based on formal evaluation results, including a pre-test/post-test on biological content and interviews of the students in the program. Written student course evaluations were also available. The experiences of the course instructors and comments by the project staff who had observed the course also played an important role in the revisions.

Course features. The courses strongly emphasized the process of science. Laboratory activities, group projects, simulations and field trips were featured, while lecturing was de-emphasized. This approach was facilitated by the format of the courses. Enrollment was held to 40 students and classes met in two, 3-hour blocks each week. As a result laboratory activities were interspersed with short lectures, discussions and other activities. Two adjacent teaching laboratories were available so that the class could be split into two groups of twenty for some activities. The availability of an experienced graduate teaching assistant able to teach one of these groups was a critical component of the program.

Applications of science and technology were also emphasized in the courses. Issues related to such things as environmental concerns, biotechnology, the importance of technology to society and the effects of weather and climate on human society are examples.

Course instructors were excellent teachers and were fully aware that part of their task was to model good teaching. We knew early in the program that their emphasis on inquiry was succeeding when the elementary education students expressed frustration because the teachers would not give them the answers, but expected them to think for themselves. The instructors were encouraged to use these courses as an opportunity to experiment with approaches that were new to them. This resulted in the development of some very creative new materials, including laboratory activities, simulations and innovative uses of educational technology. In a self-analysis of their pedagogy, the developers of the earth science course produced a series of matrices of the teaching approaches used to teach the content in the various sections of their course. A section of one matrix is shown in Table 5.

As the courses evolved through the development-teaching-revision sequence an interesting pattern emerged in the physical and life science courses. In the first round of both courses, a traditional micro to macro scale sequence of topics was used. However, the two course development teams independently decided to reverse this sequence. Instead of beginning with molecules and progressing through cells, organisms and ecosystems, the revised life science course began with global ecological issues and continued through considerations of biodiversity, structure and function of plants and animals and ending with the more abstract concepts related to cells and molecules. A similar change occurred in the organization of the physical science course. Initially the course began with the smallest particles of matter. The revised course reversed the sequence, beginning with physical and chemical properties that can be studied through hands-on experiences. As in the life science course, the more abstract concepts were not ignored, but were introduced later in the course.

Table 5
A topic/pedagogy matrix for the plate tectonics section of the earth science course.

PLATE TECTONICS

Process skills:	Patterns	Whiplash	Rocks and Minerals	Planetary Geology
critiquing	x			
measuring				
mathematics		x		
data gathering	x	x	x	
predicting	x	x		
application		x	x	x
analyzing	x	x		x
observation	x	x	x	x
classification			x	x
hypothesizing	x	x		x
modeling				x
Teaching strategies:				
cooperative learning	x	x	x	x
learning cycles	x	x	x	x
lecture	x		x	
discussion	x		x	x
drama/movies				
effective questions	x			x
lab	x	x	x	x
field trip				
computer		x		
homework	x			
packet	x		x	x
text	x		x	

The seminars. Content and pedagogy were integrated in an series of educational seminars offered concurrently with the content courses and taught by the project directors. The kinds of experiences included were classroom observations, assessment of children's understanding of science by interviewing them, journal writing, and discussion of the rationale for using various teaching approaches. The staff also taught lessons to demonstrate how content can be presented to children who are at various levels of development. Cooperative learning and a modified learning cycle were teaching/learning strategies that were emphasized because they were particularly targeted in the project. The seminars also emphasized the integration of science and language arts through the use of children's literature.

Outcomes

All three content courses and the seminars associated with them are required for all elementary education majors. Discussions are underway to ensure the sustainability of the courses. These discussions center on the allocation of FTEs among the departments providing faculty to the courses, the provision of permanent teaching space and equipment and funding for graduate teaching assistants. Other, less-focused discussions within the College of Education relate to the level of science education credit hour requirements in a curriculum that must also prepare teachers for mathematics, language arts, social studies and other content areas.

Overall, the program has been well-received and evaluation results obtained thus far have all been very positive. The major challenge for the future is to maintain the program in an environment where competition for faculty time and university resources is extremely intense.

Recommendations

The functioning of the three course development teams did not evolve uniformly. Consequently, we can provide no simple formula for the successful development of content courses. However, we can identify general guidelines for the process of course development.

1. Administrative support is essential. Acquire the support of deans and department heads before the course development teams are selected and keep them informed and involved as the project unfolds. Administrators must assure faculty members that their involvement in

the project is appreciated and will be specifically recognized in the tenure, promotion and merit pay processes.

2. Designate a project staff member to act as a facilitator for the course development. The facilitator chairs the course development sessions, gives input on questions of content and pedagogy, and serves as a liaison among team members.
3. Begin course development with open-ended sessions to allow team members to get acquainted and to find common ground in their approaches to teaching and course development.
4. Develop multiple courses one at a time, in sequence. This makes it possible for the project directors to be more effectively involved in the process and for later course development teams to benefit from the experiences of the teams that precede them.

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EARTH SCIENCE CONCEPTS FOR ELEMENTARY TEACHERS

Jay Hackett and Kathryn F. Cochran
University of Northern Colorado

This paper will describe the components of an earth science course for elementary teacher education students revised for the NSF Elementary Pre-Service Science/Mathematics Project at the University of Northern Colorado.

Course Description

The NSF project sections of Earth Science Concepts for Elementary Teachers, a three credit hour course, were arranged into two one hour sessions and one two hour laboratory session per week. Project students took the course as freshmen the fall semester of their first year on campus. They also took the Equity Issues course (see Gardner & Fitzgerald in this volume) during the same semester; and the following semester, they took the first mathematics course and the mathematics methods course.

The course was intended to provide for the following six general student outcomes:

- Improve understanding of major scientific principles related to the earth, its structure, atmosphere, and its place in space,
- understand and appreciate the nature of science,
- recognize and appreciate the relationship between science, technology, and society,
- apply mathematical skills and reasoning to experimentation and problem solving in science,
- enhance the development and application of process skills, problem solving strategies, and scientific attitudes, and
- appreciate how each of the following contributes to conceptual understanding, having concrete experiences, seeking relationships, organizing thought processes, and communicating explanations.

These six outcomes were facilitated by a focus on the four basic skills of observation, inference, measurement, and prediction; and the development of the students' skills in five integrated categories: including the manipulating and controlling variables, developing and testing hypotheses, organizing and interpreting data, developing reasonable and appropriate conclusions, and applying problem solving strategies.

The course content was organized into five broad conceptual themes with specific conceptual units embedded within each theme as described in the table below.

Broad Conceptual Themes				
Matter & Organization	Systems & Interaction	Energy & Transformation	Balance & Equilibrium	Models & Theories
Minerals & Rock Identification	Rock Cycle	Earthquakes	Geologic Time	Geologic Sequences
Cloud Classification	Temp. & Press. Fields	Water Cycle	Solar System	Plate Tectonics
Star Classification	Lunar Phases	Solar Energy		Precipitation Theory
	Seasons			

Comparison with the Traditional Version of the Course

A conscious effort was made to have the NSF project version of the course better reflect the nature of science and its influence on society. Thus, the format and delivery of the course were changed from a classical lecture/laboratory mode to a more investigative approach consistent with guided discovery instruction and learning. A deliberate attempt was made to provide problems, questions, and discussion which promote generalizations and application rather than treating concepts and principles as facts. The pace of content coverage was much slower, but the intensity of student reasoning was much greater.

The course content was selected by starting with what elementary school pupils and teachers directly experience in geology, weather, and astronomy. Emphasis was placed on natural processes and on cause and effect relationships. Reasonable explanations were constructed by the project students through active investigation of naturally-occurring phenomena and laboratory simulations. As much emphasis was placed on the search as on the solution. The major avenue through which this was accomplished was the use a modified version of the learning cycle developed by the framers of the of the Science Curriculum Instructional Study (SCIS). An example of this strategy for the first class session is presented in the table below.

LESSON 1: THE NATURE OF SCIENCE

EXPLORATION

A. Problem: Your group has been asked to enter a competition for a mural to be hung in the Smithsonian Museum in Washington. The mural is to represent "The True Nature of Science". Discuss your beliefs about the nature of science.
   1. Design and produce your mural.
   2. Develop a definition of the nature of science based on the mural.
   3. Display your mural and explain it to the class.

B. Fountain can demonstration
   1. Observe the two can fountain demonstration. Gather data to verify observations and inferences.
   2. Propose a hypothesis to explain how you believe the fountain works. Produce a drawing to show the "plumbing" inside the can.
   3. Design and conduct a series of tests of your hypothesis which can be conducted without dismantling the cans.
   4. Explain how the tests either verify or refute your hypothesis.

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EXPLANATION

A. Discuss the relationship between the approach to solving the two can problem and the nature of science.

B. Discuss the following facet of the nature of science:
   1. Use of organized and systematic methods and procedures in pursuit of questions.
   2. Holding scientific attitudes such as objectivity, suspending judgment, humility, reasonable skepticism, forming conclusions based upon interpretation of data gathered, tentative nature of findings.
   3. Acquiring a body of knowledge: facts, concepts, principles, theories, and laws.

C. Revise your definition of the nature of science based on the discussion. How might you change your mural to reflect your new ideas?

APPLICATION

A. What other models or explanations in science are like the two can problem? What other hypotheses have been tested and supported yet no one can actually look inside or take it apart to observe directly?

Examples - model of Earth's interior
- life cycle of a star
- extinction of the dinosaurs
- models for the formation of raindrops or snowflakes

B. View the film "Controversy over the Moon". Discuss the two opposing theories regarding the formation of lunar features such as the great crater Copernicus. Note how each scientist interprets the same data differently in light of their model. Which explanation seems most reasonable to you? Why? How might this controversy be resolved? Can it be resolved?

Another aspect of the project version of this course differing from the traditional version was the extent to which course activities incorporated mathematical reasoning and skills. Three of these activities are briefly described below.

- Locating Earthquake Epicenters - Students calculated the lag time between arrival times of simulated primary and secondary seismic waves. Distance to the epicenter was determined by interpreting a time/travel graph. An MECC software program entitled "Quakes" was utilized to determine the locations of epicenters from seismic arrival times.

- Relative Humidity - Using a variety of cups with different volumes, students calculated the percent of a cup's capacity filled by a given volume of water. An operational definition of relative humidity was generated from this analogy. Students then constructed a graph showing time, temperature, and relative humidity data over a 24 hour period. The graph was analyzed to determine and explain the relationship between temperature and relative humidity.

- Scale Model of the Solar System - Students demonstrated a scale model of the solar system based upon calculations of the comparative planet diameters and the distances between planets, with both size and distance on the same scale.

Efforts were also made to improve the equity of teaching strategies by being aware of the temptation to call on "target" students and to develop a broader base of teacher/student and student/student interaction. In addition, the human aspects of science were emphasized; and laboratory activities were rotated so that each student developed familiarity with equipment set up and take down. The contributions of female as well as male scientists to the fields of astronomy, geology, and meteorology were identified; and the modes of assessment were varied to accommodate the diversity in learning preferences.

As with the other target courses in this project, experienced teachers (mentor teachers) were on campus full time, and directly participated in the design, development, and delivery of the project courses. The contribution of the mentor teachers during the project has been invaluable, and we have joined the other NSF project staff and students in recommending the continued facilitation of this course and other science and mathematics content courses via the involvement of experienced mentor teachers. In addition, teaching assistant support is also vital to the course, and although the number of TAs required is approximately the same as for the traditional version of the course, the type of person needed is different. Most teaching assistants in science have little, if any, classroom teaching experience in K-12 schools. Thus, they are not familiar with guided discovery teaching methods and the use of good questioning techniques. This problem necessitates a more thorough and focused staff development program for teaching assistants, perhaps a course in college teaching.

Evaluation techniques and procedures were modified to better reflect problem solving and application to everyday phenomena rather than the recall of facts and definitions. More emphasis was placed on the continuous assessment of reasoning related to investigations throughout the semester rather than being based on a limited number of examinations.

DEVELOPING TEACHERS' MATHEMATICS AND SCIENCE CONTENT KNOWLEDGE: MATHEMATICS CONTENT

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Introduction

In September of 1987, The University of Northern Colorado was awarded a National Science Foundation grant (TEI 8751476) to improve instruction in the mathematics and science courses for prospective elementary school teachers. Two mathematics courses, Math 181 (Fundamentals of Mathematics I) and Math 182 (Fundamentals of Mathematics II), each three semester hour courses, were developed as part of this grant. Each course was taught and revised twice. The purpose of this paper is to describe the rationale and objectives, the instructional techniques used, the outcomes, and the recommendations for future use of these courses.

Rationale and Objectives of Each Course

The primary thrust of Math 181, the first of the two-course sequence, was to use an activity-oriented approach to the teaching and learning of CUPM Level One mathematics. The rationale for such an approach to teaching and learning is simple: the research literature is replete with study after study showing the efficacy of such an approach to instruction.

In addition to the above stated objective, other course objectives were as follows:

To provide a sound mathematical base for the teaching of elementary school mathematics;
To introduce Polya's four step problem-solving model;
To use an interdisciplinary approach to the teaching of mathematics;
To incorporate the use of technology in the teaching of mathematics;
To model the effective teaching of elementary mathematics;
To use cooperative learning as an instructional strategy in the classroom;
To create an awareness of mathematics as it is used in the world around us;
To reduce student mathematics anxiety in the classroom;
To emphasize the role of women and ethnic minority groups in mathematics; and
To encourage student responsibility for their learning of mathematics.

The emphasis in the Math 182 course was to use an investigative approach to the teaching and learning of mathematics and its uses in science. The rationale for such an approach was the belief that mathematics is too frequently taught without relation to any other area of study. The historical relation of science to mathematics, and the belief that elementary school teachers who are generalists have ample opportunity to integrate subject content, led to this course objective. The *Curriculum and Evaluation Standards for Teacher Evaluation* (1989) and *Professional Standards for Teaching Mathematics* (1991) from the National Council of Teachers (NCTM) substantiates the importance of integration of content in the elementary classroom.

In addition to the above-stated objective, other course objectives were as follows:

To provide a sound mathematical base for the teaching of elementary school mathematics;
To introduce Polya's four step problem-solving model;
To use an interdisciplinary approach to the teaching of mathematics especially as it pertains to science;
To incorporate the use of technology in the teaching of mathematics;
To model the teaching of integrated mathematics and science to elementary school students;
To use cooperative learning as an instructional strategy in the classroom;
To create an awareness of mathematics as it is used in the world around us;
To reduce student mathematics anxiety in the classroom;
To emphasize the role of women and ethnic minority groups in mathematics; and
To encourage student responsibility for their learning of mathematics.

Instructional Techniques

The instruction in both Math 181 and Math 182 included the use of mentor teachers, enlisted from the elementary and middle schools in the surrounding university area, to assist the college instructors in the development and teaching of the classes for preservice teachers involved in the project. The mentor teachers received their regular salaries and benefits from their home school districts. Salaries for mentor teacher substitute classroom teachers were paid with monies from the grant. In addition, an academic year stipend of $1500 was made available to each mentor teacher to be used for graduate coursework, professional meetings or conferences, or for other costs associated with their involvement in the project. Further information on mentor teachers can be obtained from McNerney's paper *The Use of Mentor Teachers in the College Mathematics Classroom* (1992). (This paper has been submitted for publication but copies may be obtained by writing to the author.)

Mathematical content for Math 181 included problem-solving strategies, sets, relations and functions, numeration, the systems of whole numbers, integers, and rational numbers, the computational algorithms associated with these systems, and elementary number theory. Billstein's *Mathematics for Elementary Teachers, Third Edition* (1987) was the textbook used.

Manipulatives used in Math 181 included activities with pattern blocks, attribute blocks, geoboards, base ten blocks, the abacus, colored crayons, and non-commercial items. Numerous paper handouts were used with these manipulatives.

Handheld calculators were used throughout both courses to model their use in elementary mathematics. The Apple II/e was used with teams of two students to illustrate the use of commercial software such as *The Factory* in problem solving. An introduction to LogoWriter was also provided in Math 181.

All instruction in both courses, including the review of homework assignments, took place in a cooperative learning setting. Students in Math 181 worked at hexagonal tables, four to five students to a table. An overhead projector was used for instruction with the students encouraged to use it to give explanations and to demonstrate solutions.

The integrated content for the Math 182 included non-decimal numeration with its relation to computers and binary coding; decimals and their operations with an emphasis on the use of scientific notation in determining the time necessary to send a message from Neptune to Earth during the Neptune probe; the system of real numbers; the use of the Pythagorean relationship and the tangent function to determine road gradients, the heights of buildings, and rocket launches conducted by the students; probability with its use in genetics, statistics, and graphs with concomitant use in scattergrams, and introductory plane and solid geometry with its uses in light refraction and crystallography; and measurement systems including experiments using metrication.

Goodstein's *Sci-Math* (1987) was used as a supplementary textbook in the course to introduce denominate numbers, unitary and reciprocal rates, and the development of direct and inverse proportions and their equations. Experiments with C clamps were used to illustrate direct variation while other manipulatives such as bicycle tire pumps were used to relate pressure and volume. Because the class was taught in a science classroom, the instructional environment was conducive to experimentation.

Course Outcomes

Each mathematics course was evaluated by instructor-made examinations to determine students' grades for the course. Two one-hour examinations and a two-hour final examination were given each semester. In addition, written teacher evaluations of each lesson were done by the mentor teachers and were shared with the instructor and the project directors.

Additional non-standardized tests over the course material were alsogiven for each course. These tests were constructed by the instructor and one of the project the co-directors. The results of these tests were shared with the instructors and are part of the permanent project assessment.

Informal and formal class evaluations conducted by the instructor and mentor teachers, although not research based, suggest the following conclusions for the Math 181 course:

- The activity approach was successful affectively. Whether or not the activities were significantly beneficial cognitively was more difficult to demonstrate. Questionnaires indicated an intense interest and enjoyment in these activities. The students also used various forms of the activities when they participated in their cadet teaching, a classroom experience required as part of their mathematics methods class.

- Examples from literature, science, and other sources outside the domain of mathematics were used in the classroom instruction. Students were asked to keep a notebook of connections between mathematics and other areas of the curriculum as a course requirement. These notebooks were collected twice during the semester and the results indicated that the students were using good, non-trivial examples of the use of mathematics in the "outside world."

- Questionnaires again indicated that the vast majority of the students enjoyed the course, were not mathematically anxious, felt an awareness of the gender and ethnic implications of teaching mathematics, and looked forward to teaching mathematics upon entry in to the profession after graduation. The use of mentor teachers was considered by the students to be one of the, if not the, most beneficial aspect(s) of the instruction.

Once again, informal and formal class evaluations conducted by the instructor and mentor teachers, although not research based, suggest the following conclusions for the Math 182 course:

- The lab approach to the teaching of the integration of mathematics and science was extremely well received by students. Most students commented in the questionnaires they were asked to complete that they thoroughly enjoyed the integration of mathematics and science. Informal conversations with university instructors who taught these same students in their physical science courses indicated that they could teach much more science to the students because students "seemed to understand and be able to use mathematics in a science setting."
- As with the Math 181 course, concerns regarding cooperative learning, gender and ethnicity issues, and mathematics anxiety appeared to be positive. Again, the mentor teacher was considered outstanding.
- Lest one think that there were no negative aspects concerning the conduct of the two courses, it must be said that some students, at times, felt that tests given by the instructor were too difficult, the assignments were too long, and that tests in Math 181 did not measure what went on in the classroom instruction, namely, they did not measure classroom use of manipulatives. There were also differences between the instructor and some students regarding day to day items such as lack of attention, failure to do homework, and the like. The Math 182 course seemed to go more smoothly, possibly because the instructor knew the students from the previous course. There were students who still felt the tests were too difficult, the time not sufficient to finish the tests, etc.

It should be stated that not all students passed either the Math 181 or the Math 182 courses (9.5% of the students failed Math 181 and 13% failed Math 182). These students were required to retake the courses if they wanted to remain in the project.

Recommendations

Any recommendations put forth by this instructor must necessarily be based upon non-scientific data. The project directors undoubtedly, at the time of this writing, have better data upon which to make recommendations than does the instructor. The instructor does have the benefit of 23 years of experience in the mathematical preparation of prospective elementary school teachers and will base his recommendations primarily upon this experience.

Manipulatives should be used in the teaching of a Math 181 - type course. The mathematics education community would undoubtedly expect this recommendation. What is not so clear is *how much usage of manipulatives is appropriate.*

The Math 181 course was taught twice as was the Math 182 course. Possibly, manipulatives were *overused* the first time that Math 181 was taught. The use of manipulatives takes time, even with the help of one or, in some cases, two mentor teachers. Consequently, because of their daily use, time was not available during the semester for course content that was considered valuable for these students. The revision of the course included the use of activities, on average, every second or third lesson. The students still enjoyed the course, the course objectives were met, and there was adequate time for course content coverage.

Cooperative learning, gender and ethnic issues, problem-solving, the use of mentor teachers, and other items addressed in these experimental courses can, and should, be included in Math 181 and Math 182 - type courses. It is felt that significant positive student outcomes will accompany implementation of these features.

However, it must be said that the most positive effect of these approaches was upon the classroom instructor. The benefits of innovative teaching will be carried over to future non-project classes.

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LEARNING CYCLES FOR A LARGE-ENROLLMENT CLASS*

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Recent attention to precollege science education has once again emphasized two important conclusions:

1) Children are frequently "turned-off" from science in elementary school and are unlikely to change that attitude in later years, and
2) Elementary school teachers are seldom adequately prepared to teach science.

Most physicists will accept these conclusions without documentation. Their reactions are frequently to admonish colleges of education with, "Too many methods courses; not enough hard science."

Yet, when we look at the average physics course taken by elementary-education majors and other nonscience majors, we can see our contribution to the problem. Introductory physics courses are generally regarded by students as a collection of facts. While we try to teach reasoning skills and understanding in a survey course, we present such a large quantity of information that most students react by memorizing. They view science as knowledge to be recalled.

We should not be surprised, then, that school teachers frequently feel inadequately prepared to teach science. How can they possibly recall all they need to remember to teach physics, chemistry, biology, earth science, and so on? The answer is that they do not need to recall it. Science is not a collection of facts but a way of observing, collecting data, critically thinking, building models, and comparing with nature. Teachers who understand this concept should be much more comfortable with science.

To address this criticism of typical science courses, several physicists have developed courses for future teachers that emphasize the nature of physics and the reasoning involved in science.[1] The design of these courses is frequently based on the Piagetian model of intellectual development.[2] The most common way of teaching these introductory physics courses is with class sizes of 20 to 30 and a large quantity of hands-on materials.

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The economics associated with small class size has limited adoption of this method at many universities, including mine. To overcome this difficulty, I have adapted a general learning/teaching model for a class of about 100 students with one faculty member assigned to it. During the past ten years the course has evolved into one with an emphasis on the nature of science and on learning science by doing science.

Although this course has been developed for elementary-education majors, it could be used equally well for other nonscience majors. Because the course is a physics course, its content is not unique to future teachers. More generally, the design of the course could be used to address disenchantments with the introductory course, such as those recently stated by Strassenburg[3]:

- lectures as the principal mechanism for transmitting information
- textbook problems as the major student activity and evaluation mechanisms
- the laboratory portion of the course
- the failure to use computers effectively
- the absence of significant amounts of quantum physics

The course described here addresses all the problems but the last.

Course Design

The course is constructed of 15 activity-based units, each of which is one-week long. An activity-based unit is a learning experience that focuses on a series of eight to ten short experiments performed by all of the students in the class. Thus, students perform a large number of experiments and these activities form the backbone of the course.

Each unit involves hands-on activities and is based on the learning cycle format developed by Robert Karplus.[4] The learning cycle is derived from the intellectual development model of Jean Piaget[3] and includes three different types of activities. The first activity, *exploration*, requires the student to explore a concept by performing a series of activities. Students are given a general goal, some equipment, and some general ideas about the concepts involved. They are asked to explore the concept experimentally, in as much detail as they can, and to relate it to other experiences they have had. The second phase of the learning cycle, *concept introduction*, provides a model or concept to explain observations of the exploration. Frequently, the concept-introduction stage is not an experimental activity but an expository statement of concepts and principles. Following the concept introduction, the students move to *concept application.* Here, they use the concepts that were introduced and apply them to new situations. This application of the principles and concepts leads to further understanding of the theories and the models. The complete cycle has been used successfully to teach a wide variety of topics to students at all grade levels.[5]

The learning cycle has been used successfully for small-enrollment physics classes at several institutions, including the University of Washington in Seattle, Fairleigh Dickinson University, and the University of Nebraska at Lincoln.[6] These universities offer courses taught in a laboratory setting to small groups of students, usually 20 to 30 per section. At Kansas State University we are required to teach the physics course for elementary-education majors in one large section. (The enrollment is approximately 100 students per semester.) Thus, the methods of the learning cycle had to be varied to fit the requirements imposed by one large class.

To adapt the learning cycle for a large-enrollment course taught by a single faculty member, we use a combination of activities completed in an open laboratory environment and large class meetings. This adaptation utilizes the KSU Physics Activities Center,[7] a learning center that is open about 30 hours per week. The format we use is outlined here.

Exploration. This part of the learning cycle is a series of hands-on activities. In the usual approach, exploration requires a large amount of student-teacher and student-student interaction. In our adaptation, some of the student-teacher interaction is replaced by activity instruction sheets and instructional media. A teaching assistant is always available in the activities center so that a student is able to interact with a teacher. However, the assistant cannot be available to all students. Thus, most of the exploration is performed by students working alone or in small groups.

Concept introduction. One large class meeting each week is devoted to this phase. Students are asked to describe their exploration observations and any related experiences. Using these observations, the instructor guides the students toward a model or a theory that can be used to explain the observations.

Concept application. The final phase of the cycle again involves hands-on activities. Using the model developed in the large class (concept-introduction phase), the students make predictions for new situations. Their predictions are tested experimentally in the physics activities center. As in the exploration phase, instruction sheets, instructional media, and teaching assistants are available. Additional applications and summaries are discussed in a large class meeting. This learning cycle is shown schematically in Figure 1.

The teaching assistants in the activities center are available to help all students in all physics courses. Thus, their availability to students in this course is limited to answering short questions. The assistants act as proctors who help with occasional conceptual or equipment difficulties rather than as instructors in the course.

Operation of the Course

This adaptation of the learning cycle fits nicely into a standard Monday-Wednesday-Friday university schedule (see Table 1). Each cycle begins on Monday afternoon. At that time, the equipment for the exploration in the unit is available in the physics activities center. Students must complete all exploration activities before class meets on Wednesday. The concepts that were explored are introduced in a lecture discussion format during a 50-minute class on Wednesday. Following this class meeting, the application equipment is available until class time on Friday. The class meets on Friday to ask questions about the week's work. In addition, the concepts introduced on Wednesday are applied to situations that, usually, lead to questions not easily answered with present knowledge. These applications introduce the exploration of the next cycle. Monday morning classes are utilized for answering further questions, summarizing the previous week's activities, and giving examinations.

Each exploration and application is composed of six to eight short experiments called activities. The equipment for each activity is placed in the physics activities center at marked stations. The students are told what equipment is located at each station and presented with questions to answer about it. For example, an application activity on electrostatics states: "At station EM-9 is a small Wimshurst Machine. By turning the crank you can charge the two spheres. A small aluminum ball is suspended between the spheres. Describe and explain the motion of the ball as you turn the crank."

The students are guided from station to station until they complete all activities. For each activity they must write answers to all questions on their activity sheets. When they finish, the students leave the completed activity sheets in the activity center.

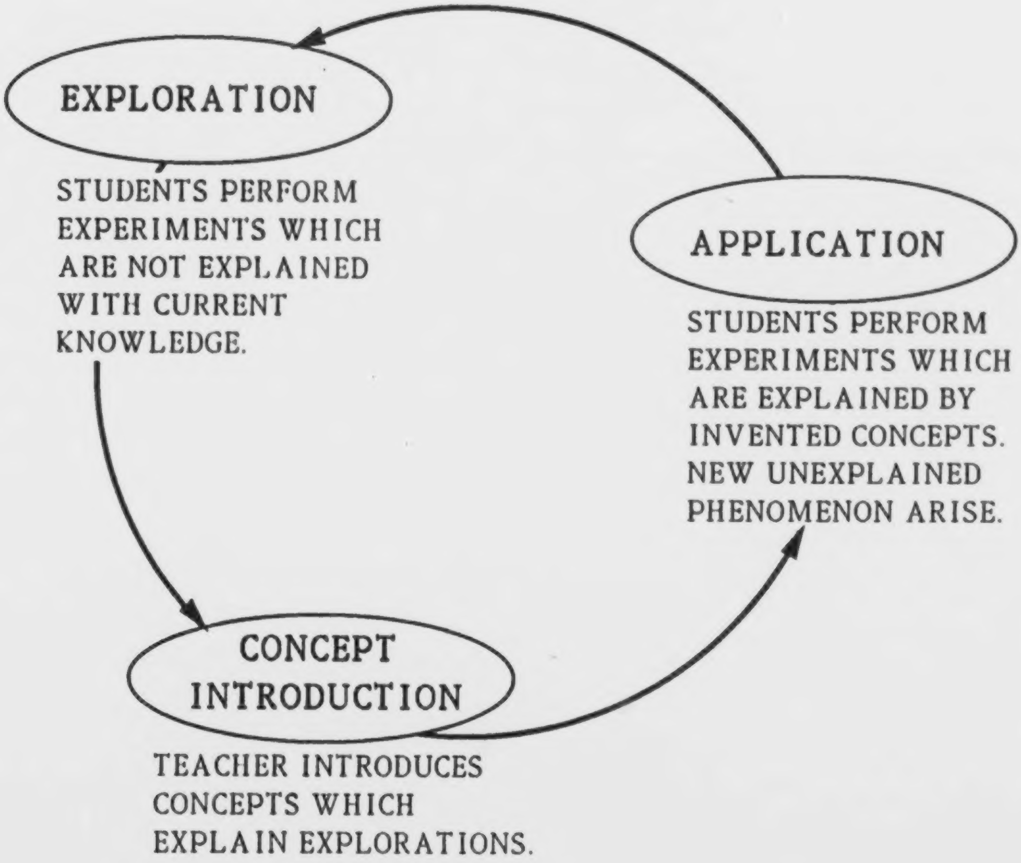
EXPLORATION
STUDENTS PERFORM EXPERIMENTS WHICH ARE NOT EXPLAINED WITH CURRENT KNOWLEDGE.
APPLICATION
STUDENTS PERFORM EXPERIMENTS WHICH ARE EXPLAINED BY INVENTED CONCEPTS. NEW UNEXPLAINED PHENOMENON ARISE.
CONCEPT INTRODUCTION
TEACHER INTRODUCES CONCEPTS WHICH EXPLAIN EXPLORATIONS.

Figure 1
The Learning Cycle is used as a method of teaching physics.

Table 1
Schedule for the Learning Cycle.

	In Activities Center	In Large Class Meetings
Monday PM	Exploration	Further questions and applications
Tuesday	Exploration	
Wednesday AM	Exploration	Concept introduction
Wednesday PM	Application	
Thursday	Application	
Friday AM	Application	Further applications
Monday AM		Tests, discussion of student questions, summary of the unit

To assure that students are adequately motivated to complete the activities, grades are assigned to each exploration and application. Explorations are graded on a Satisfactory/Unsatisfactory basis. To obtain a Satisfactory, a student must try to answer each question on the activities sheet. There are no right or wrong answers--only attempts at exploring new phenomena. Each Satisfactory is translated into five points when course grades are calculated. No points are given for an Unsatisfactory.

The applications are graded on a scale of 0 to 10. In this case, grades are based on the students' abilities to use physics concepts in their explanations and to use those quantitative relationships presented in the class and text.[8]

A student's course grade is computed by utilizing the following components (maximum points possible are indicated in parentheses): exploration (75), application (150), tests (400), and final exam (200).

Sample Learning Cycle

As an example of a week's activity in this class, consider the first of five weeks on the topic of energy. When students start the exploration, they have already studied kinematics, momentum, and forces. Thus, they begin by trying to explain the motion of a pendulum by using either conservation of momentum or Newton's laws. Then they look at several experiments involving motion and change of motion. (At this point the term *energy* has not been introduced.)

First, a toy car is rolled down an incline into an aluminum can. By releasing the car from several different locations on the incline, the students determine qualitatively the relationship between release location and damage to the can.[9] The activity sheet then instructs the students to change the angle of the incline and repeat the experiments. (A similar experiment involves driving nails by dropping weights on them. They compare the distance the nail is driven for different release heights and different-sized weights.)

The exploration concludes with a station at which the cart and can are placed on a horizontal surface. The students are asked to make a dent in the can without lifting the cart or can from the table. Once they accomplish that, they are asked to do something to make a bigger dent. Most students decide to move the cart at a higher speed; a few think of adding mass to it.

After completing the exploration, the students express in writing any similarities they can see in the various observation activities. These statements

Table 2. Descriptions of interactive video activities using videodiscs.

Who's Upside Down?
Frames of References
Students must determine which of two people is upside down and type reasons for their conclusions into the computer.

What's Moving?
Frames of Reference
By using slow motions, students measure speeds in two seemingly identical situations. They are then asked to determine whether it is the person or the background that is moving in each of the scenes.

Did Anyone Get Hit?
Pioneer Demonstration Videodisc
Students view a controversial "punch" in a prize fight between M. Ali and S. Liston. They use slow motion to look at the scene closely then use conservation of momentum to discuss whether or not Ali's punch actually hit Liston.

Air Bags and Impulse
Physics and Automobile Collisions
Students measure the impact time for mannequins as an automobile strikes a wall. One mannequin collides with the windshield and dashboard, while the other collides with an air bag. Then the students apply their knowledge of impulse to the scene.

Hammer and Feather on the Moon
Spacedisc 2. Apollo
Student measure the fall of a hammer and a feather that were dropped by an astronaut who was standing on the surface of the moon. Students complete the same experiment on earth and compare their results with the experiment on the moon.

Seat Belts and Inertia
Physics and Automobile Collisions
Students analyze the motion of a mannequin during an automobile collision. The mannequin is restrained by a seat belt and shoulder strap. They contrast the motion of the mannequin's head with that of its body. Then they apply Newton's laws to describe their observations.

Forces on a Diver
Studies in Motion
Students analyze the forces on a diver from the time she steps onto the diving board until she is submerged in the water.

Waves and Resonance
The Puzzle of the Tacoma Narrows Bridge
Students study the properties of wave motion and resonance by completing the lesson prepared for this videodisc. Wave motion is not presented at any other time in the course, so this videodisc lesson is the treatment presented.

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will be in their own language since we have not yet introduced the vocabulary of energy-related concepts.

The concept introduction begins with a discussion of the difficulties involved in describing the motion of the pendulum and with the "exchange of something" that causes the pendulum to move fast at the bottom and slow at the top of its swing. The discussion is primarily student centered. The instructor leads off with a question, but the students do most of the talking. The discussion motivates a reason for introducing a new concept.

The general concepts of energy and gravitational potential energy are introduced. Students, by referring to their observations during the exploration, provide a list of variables upon which the potential energy depends. By recalling the nail-driving activities, they can also state the functional dependence of gravitational potential energy on mass and height.

A similar discussion and student-centered introduction occurs for kinetic energy. Most students will state that kinetic energy depends on speed. (However, none of the activities have enabled them to determine the functional dependence.) A few students will have discovered that adding mass to the cart will have an effect. (Two bricks are sitting at the activity station but are not discussed in the instructions.) Thus, with guidance from the instructor and frequent reference to their exploration activities, the students construct the basic ideas of mechanical energy.

To conclude the introduction, we return to the pendulum and develop the idea of conservation of energy. With this material (which closely parallels the textbook[8]) the students are ready to begin the concept application.

The beginning of the application is simply a check to determine if the students can plug numbers correctly into the equations. After measuring their masses and walking speeds, they calculate their kinetic energies while walking and their change in gravitational potential energies when they move from the first to second floor of the physics building. For the next activity, they return to the nail driver, calculate its potential energy at several heights, and use conservation of energy to state its kinetic energy just before it hits the nail. Even though they have "learned" conservation of energy, many students reach a state of disequilibrium here. "How can I determine kinetic energy when I don't know the speed?" is a frequent question. Without the application, the students would not have noticed this problem in their learning until the next test. With this concrete example, they are able to address it at once.

A slot-car racer with a loop-the-loop track is the equipment for the next activity. The students are asked to measure the height of the loop and predict the kinetic energy needed for a car to go through it. Using a photocell timer, the students determine the speed and calculate the kinetic energy at the bottom of the loop. When they compare the actual kinetic energy with their prediction, they find a significant discrepancy. The students are asked to speculate about the reason for differences between these two numbers and told that we will discuss it during Friday's class.

Next, the students drop a feather and a BB from the same height. The two objects have equal mass so they begin with the same potential energy (which the students calculate). Without making any measurements, all students notice that the two objects have different kinetic energies as they reach the floor. Again, they speculate about these differences.

Finally a two-hill "roller coaster" track is used. The students are asked to predict, then experimentally determine, the point on the higher hill from which a steel ball must be released to roll over the lower hill. The experiment is repeated with a cork-covered ball of the same mass. They discuss the differences between these results and the results predicted by conservation of potential and kinetic energy.

After answering questions during Friday's class meeting, we continue looking at situations wherein the sum of kinetic and gravitation potential energies is not conserved. Particular attention is paid to the differences between the BB and the feather and between the bare steel and cork-covered balls. Because the students have studied friction, they speculate that it must be involved. A discussion of work by a frictional force prepares the students for the next activity--exploring thermal energy.

In this example of our adapted learning cycle, students used traditional laboratory equipment to perform all observations and measurements. However, other cycles include activities based on videodiscs, film loops, videotapes, slide sets, and computer simulations. A list of the videodisc-based activities are presented in Table 2. In all activities, including the ones based on computer technology, students must answer questions, in writing, about their observations and measurements.

Course Coverage

All instructors who use the learning cycle and similar approaches report that they cannot cover as many topics as in a traditional course.[10] This course is no exception. So we choose to include the topics that could be of greatest value to the elementary-school teacher. The schedule with topics is shown in Table 3. These topics appear in most elementary science curricula. (An exception is the second law of thermodynamics, which we believe is important for understanding the world's energy problems.)

We still cannot cover all of the topics included in all elementary curricula. However, we emphasize the nature of learning science and trust that the students will be able to acquire knowledge of additional topics as they need it.

Effectiveness of the Course

To determine the effectiveness of this course, the Office of Planning and Evaluation at Kansas State University performed an independent evaluation of student learning and attitudes. Attitudes were assessed through a student feedback on instruction form. Student learning was examined by administering essentially identical final examinations to two classes. Both classes were taught by the same instructor--one by standard lecture procedures; the other by the learning cycle described above. Students' ratings of the instructor were essentially equal for both courses. No differences in attitudes were detected.

To investigate student learning, the final examination was analyzed in two ways. First, the exam score was divided into four partial scores representing the major topics--space and time, forces, energy, and electricity and magnetism. Second, the exam questions were analyzed in terms of the type of "effort" needed to answer the questions. Three types--calculation, conceptual explanation, and recall--were identified. In all analyses the students' cumulative grade-point averages were used as a covariate to control for different learning capacities.

For all topic categories, the learning-cycle group scored higher than the lecture group. The differences in the score for forces and energy were statistically significant. When analyzed for type of effort, the scores showed that the learning-cycle group scored higher on conceptual explanations and calculations but lower on recall questions. However, none of the differences were statistically significant. Thus, the evaluation of the course showed that the learning-cycle course contributed positively to student understanding of forces and energy.

Table 3
Topics in the course.

Week	Content
1	Relative position and motion
2	Speed, velocity, displacement, relative speed
3	Momentum, conservation, interactions
4	Force: Newton's laws
5	Newton's laws (continued): Rotation reference systems
6	Newton's laws (continued): Multiple force
7	Fundamental interactions
8	Gravitational potential energy, kinetic energy, conservation of energy
9	Thermal energy: Specific heat capacity
10	Thermal energy: Convection and radiation
11	Thermal energy: Conduction
12	Thermodynamics
13	Single circuits: Ohm's law
14	Series and parallel circuits
15	Magnetism (briefly)

Instructor's Impressions

The most obvious difference between this course and a lecture course is the immediate feedback received by the students. By the time they come to class on Friday, students have been forced to use the material presented on Wednesday. If they had difficulties, they ask questions. Frequently, students will seek help from fellow students; thus, interaction among students is much greater than in a lecture class.

The interaction during the large class sessions is also much greater than that occurring in most classes of 100 or more students. The activity format seems to establish a less formal atmosphere in the lecture hall. Students respond to questions from the instructor. Because they know that they must use the concepts immediately, the students frequently interrupt the discussion to ask for clarifications. Student/teacher interaction is much greater than in most large classes.

Most students see almost immediately the value of the application activities. However, early in the semester the explorations are considered less valuable. Many students complain that the goals of the exploration are not specific. They do not know what they are supposed to do. (Of course, specific statements of goals would defeat the purpose of the explorations.) As with most instruction, a concrete example is the best teacher. By the time they complete a few learning cycles, most students see that the explorations are preparing them to learn new concepts. When they see that grades of Satisfactory are given for what *they* do, not for meeting an unstated objective, they feel free to explore phenomena in a variety of ways. Thus, the explorations, which seem confusing and sometimes frustrating at the beginning of the semester, become enjoyable learning experiences.

The activities become the vehicle for learning physics. Many students have stated that they do not know how physics could be learned any other way. I, for one, certainly would not return to teaching it by the lecture method.

Acknowledgments

The author was aided in the development of some activities by James Langford and Dean Stramel. The evaluation was completed by William Pallet. The course began in 1978 with support from the Local Course Improvement Program of the National Science Foundation under grant number SER 79-00507. Continued development has been supported by Kansas State University.

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PHYSICAL SCIENCE FOR ELEMENTARY EDUCATION MAJORS AT INDIANA UNIVERSITY

Catherine Olmer
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Introduction

The Physics Department at Indiana University offers a one-semester (15 week) 3-credit introductory physics course, Q202: Physical Science for Elementary Education Majors, which is offered during both the fall and spring semesters. Q202 is now required of all elementary education majors in the IU School of Education, and approximately 150 students enroll in this course each semester.

Each week, the students attend two 50-minute lectures which I present, as well as one 3-hour lab which is taught by Physics Department graduate students (AIs). An enrollment limit of 15 students per lab section is maintained, and the students work together in groups of 3 students per laboratory table.

There are three main goals to Q202:

1. We must teach our students the ideas, the methods, and the excitement of physics, as well as the relevance of physics to everyday lives.
2. We must excite and interest our students in physics, so that they come to believe that physics is enjoyable and not intimidating. Our students must enjoy physics and look forward to teaching physics to children.
3. We must show our students how physics can be effectively and enjoyably conveyed to children, so that our students will be able to teach it successfully.

The attitudes of the professor and AIs are instrumental to the success of Q202. We must ourselves be enthusiastic and excited about physics and teaching the course. We must make the physics relevant to everyday lives, as well as to the prospective careers of their students. We must always be patient, caring, concerned and understanding; we must be willing to individually help each student. Moreover, we must respect the students, and treat them as future colleagues and professionals.

The lectures in Q202 present explanations of the physics concepts, as well as qualitative and quantitative examples. Demonstrations and experiments are often presented to illustrate the physics, and always use simple, easily available materials. While the large lecture hall may not be as conducive as a small room for student-initiated questions and discussions, we find that, when encouraged, the students freely ask and answer questions during the lecture.

The laboratory activities in Q202 are all suitable for use in the elementary schools. These inquiry-based labs combine both conceptual as well as quantitative activities, and all use simple, easily available materials. Several labs include "make-and-take" activities, in which the students construct various projects which they can keep. A detailed discussion of several projects is presented below. Several labs employ computer-aided activities, in which the computer is utilized in obtaining and analyzing data. A detailed discussion of these computer labs is presented below.

Finally, the course includes three research projects which the students carry out at home. The purpose of these projects is to encourage the students to do physics in an independent, self-directed way, and to experience the joy and the excitement of inquiry and discovery. A detailed discussion of these projects is presented below.

Physics Topics in Q202

As with all courses in the Physics Department, the faculty member assigned to this course selects the topics for presentation. Since I first began teaching this course in 1984, the breadth and depth of topics which I have presented, as well as the activities which I require of the students have greatly evolved. There are now fewer topics included in Q202 than in the past, and the scope of these topics is to provide experiences relevant for elementary school science teachers.

I stress a conceptual understanding of physics (heavier vs. lighter, faster vs. slower, brighter vs. dimmer, shorter vs. longer), with some basic algebra used for a quantitative understanding of selected topics. While protractors are used to determine angles in ray-tracing activities for reflection, no trigonometry is used.

The selection of topics to be included in Q202 is an eternal source of concern. During the spring, 1992 semester, the following topics were presented:

1. Light (5 weeks):
    - reflection with flat and curved mirrors
    - refraction
    - color

2. Electricity and Magnetism (5 weeks):
   - static electricity
   - current electricity (batteries and bulbs, series and parallel)
   - household considerations (fuse, circuit breakers, 3-way bulbs, etc.)
   - permanent and temporary magnets; electromagnets
3. Motion and Forces (5 weeks):
   - straight line motion (mainly conceptual, some quantitative)
   - mainly distance and velocity; some acceleration
   - forces and Newton's First Law
   - center of mass, torque and balance

The weekly laboratory activities complement these topics, and also include limited additional activities in sound and kitchen chemistry during exam weeks. Other major topics have been presented in earlier semesters, replacing some of the above units. These have included a 3 week unit on heat and temperature, as well as a 3-4 week unit on properties of liquids and gases.

It is clear that while it might be tempting to a physics professor to expose these prospective elementary teachers to as many different areas of physics as possible, such actions would be disastrous. Most of the students have never previously taken a physics course, and nearly all of the students enter the class with intense fear and anxiety. It is crucial to limit the amount of material being presented, to make that material student-friendly and relevant for elementary school science, and to provide the students with sufficient time to digest and become comfortable with the material and to make the material part of their knowledge base.

Make-And-Take Activities In The Laboratory

Each semester, the students build and keep several "make-and-take" activities in the lab. These activities are among the most enjoyable and memorable parts of the course for the students, and provide them with projects which they can carry over to their future careers as science teachers. Many of these projects were demonstrated at the conference, and all involve inexpensive and readily available materials. Some of the "make-and-take" activities include the following:

Light

1. *Kaleidoscope*: The students construct and keep kaleidoscopes built with empty toilet rolls (provided by the students), mylar trim ($2.40 for a 5"x36" sheet purchased from a local hobby shop; note this has reflection properties

superior to balloon mylar, and is much easier to use), clear plastic craft cups (purchased from local craft store) and colored plastic beads (purchased from local craft store).

2. *Chromatogram*: The students do chromatography experiments using water, Melitta coffee filters (superior in performance to generic) and water-based felt-tip pens such as Mr. Sketch. A tongue is cut halfway into a circular filter, and is then marked and suspended in water. The resulting patterns of separated colors completely cover the circular filter, are quite beautiful, and more clearly show the constituent dyes within the pen color than the traditional rectangular-strip chromatography.

Electricity and Magnetism

1. *Electric test board*: The students construct an electric test board, suitable for matching tests in which answers are listed in an order different from the questions. The materials include a battery (provided by the students), manila file folder, aluminum foil, masking tape, and an individual Christmas tree light (cut from a long strand; one light will work with two 1.5 volt batteries or one 6-volt battery).
2. *Electrical switches*: The students construct a simple switch (on/off) and a double switch using aluminum foil, masking tape, 3"x5" cards, paper clips and metal paper fasteners. These switches are then used to investigate electrical circuits using batteries and separate Christmas tree lights.
3. *Compass*: The students construct a compass to investigate magnetic fields using thread, a sewing needle and a clear plastic cup.

Balance and Center of Mass

1. *Balancing parrots*: The students construct a cardboard parrot which cannot be normally balanced, but which will be easily balanced on the finger when the center of mass of the parrot is adjusted using pennies and sticky-tack.
2. *Single arm balance*: The students construct a single arm balance using an 18" wood lath strip (cut in school machine shop or purchased from a local lumber store at $50 for 180 strips), masking tape and paper clips. The students calibrate their balance using units of M&M candies, which are uniform in mass and each slightly less than 1 gram.

While these and other similar "make-and-take" activities are clearly enjoyable to the students, we also stress a deep understanding of the physics material contained within the activity. Each activity is accompanied by qualitative and quantitative questions as the students are guided through the activity. Nearly all of these activities are followed up by homework and/or exam questions probing the students' level of understanding of the underlying physics.

Computer Aided Activities In The Laboratory

As part of its commitment to Dorothy Gabel's QUEST project, Indiana University provided $12,000 to install computer activities in the Q202 lab. With these funds, we have purchased 4 Macintosh LC computers (with a 5th SE computer on long-term loan from the department), 1 laser printer, 5 computer interface boxes (ULIs), 5 sonic rangers and 10 temperature probes; the hardware and software were purchased from Vernier Scientific Company. Many of the lab write-ups were developed in the very successful program of Prof. Ronald Thornton at the Center for Science Teaching, Department of Education, Tufts University; other lab write-ups were developed at IU by Mr. Michael Svec and me. The computers were installed during the summer of 1991, and were used during the ensuing two semesters.

Many elementary schools presently have computers available to the students. It is our understanding that these computers are used mainly as word processors or to run stand-alone programs. In Q202, we decided to concentrate on using the computer as a device which assists in carrying out experiments and analyzing the results. We have focussed on two major areas of investigation.

Heat and temperature. We have used the computers with temperature probes to provide a quick, easy and accurate measurement of temperature as a function of time in order to provide the students with time to think during the experiments (rather than to mindlessly read a thermometer ever minute or so); to provide results which are accurate, reproducible, and can show changes or effects not generally visible in thermometer-based experiments; and to provide the students with the ability to easily repeat an experiment or to try new variations on an experiment.

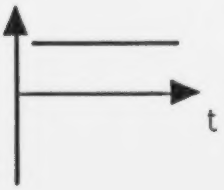
The students investigated the following phenomena:

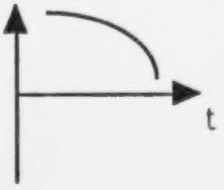
- evaporation and cooling
- the differences between heat and temperature
- mixing water of different volumes, at different temperatures
- heating water and other substances (such as cooking oil) in order to compare the rate of heating
- measuring the specific heat of pennies

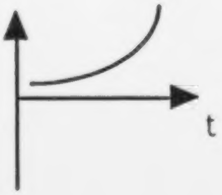
These labs were generally successful with the standard temperature probes, although some hardware problems were experienced with prototype heaters and a new style of probe. It is clear to us that using the computer to investigate heat and temperature is superior to more traditional methods.

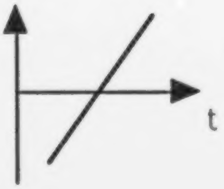
Motion. We have also used the computers with sonic rangers to investigate questions of motion. The sonic ranger works like the range finder on a camera, and emits high-pitched sound waves. These waves travel outwards, encounter an obstruction and are reflected back to the sonic ranger unit where they are detected. The computer uses the time between the sound pulse leaving the ranger and returning to the ranger, together with the speed of sound in air, to deduce how far away the obstruction is located. This distance is then determined for subsequent times. The computer displays the distance as a function of time and can use these results to determine the velocity of the object (how the distance changes with time), as well as the acceleration of the object (how the velocity changes with time).

The students investigated the motion of their own bodies in front of the sonic ranger, as well as the motion of a toy car on a flat surface or on an inclined ramp. The students measured and examined graphs of distance, velocity and acceleration as functions of time, e.g.









Investigating these graphs involves addressing questions such as: What does it mean for distance or velocity to be zero? to be constant with time? to be positive or negative? What can we infer about one quantity based on our observation of the other? We stress that the students be able to read a description of the motion (in everyday words) and from this predict the graphs, as well as the reverse skill of being able to describe the motion based only on an observation of the graphs. We find that such activities greatly enhance the abilities of the students to use and to read graphs.

In addition to the computer labs on motion, we have also incorporated several "low-tech" activities using stop watches to measure the motion of walking or running students, and balls rolling down ramps. The purpose of these activities is to enhance and reinforce the ideas of motion examined in the computer labs, and to provide our future teachers who do not have access to computers with some hands-on activities in motion.

As most physics teachers will agree, students generally have a difficult time understanding the ideas of motion. We evaluated the success of our motion unit by administering a pretest (prior to the motion unit) and a post-test (at the end of the semester) during the fall, 1991 and spring, 1992 semesters. (The tests were provided by Prof. Thornton.) The analysis of the pretest and post-test responses was carried out by Prof. William Boone and Mr. Michael Svec, in the Science Education Department at IU. Their imaginative program allows us to examine correlations between the pretest and post-test responses of students, and thus to follow how the students' understanding and misconceptions are evolving.

The results from a comparison of the pretest and post-test responses are remarkable, and clearly demonstrate the effectiveness of these computer-based activities in facilitating the students' understanding of motion. Several examples are provided in Figures 1, 2 and 3 at the end of this paper, with the indicated percentages showing the students who selected each response. The correct answer is indicated by the arrow. A more complete publication of these results, including the new information provided by the correlation data, is in progress.

Research Projects

As a physicist specializing in experimental nuclear physics, I realize that my own profound enjoyment of physics comes from actually doing physics. My excitement for physics is continuously renewed by my carrying out some physics experiment: constructing something which illustrates a physics principle or making something work or probing our understanding of the physical world, and then explaining to others why things worked the way they did. There is not much excitement to be derived vicariously from reading about physics or by watching somebody else do physics.

I believe it is crucial that our future elementary science teachers experience this excitement and thrill which comes from doing science and being a scientist. For this reason, I have scheduled three independent projects which the students complete at home (or more likely, in the dorms, fraternities, or sororities) and present in the Q202 lab.

1. The students grow large (1"-2") crystals. The students are provided with 50-100 grams of copper sulfate (available from pool or farm stores), epsom salts (available at drug stores) or potassium aluminum sulfate (available from science supply companies). Detailed instructions are provided to the students to use hot water to dissolve the powder, to grow crystal seeds and finally to grow a single large crystal. The students bring their large crystals to lab during the last week of the semester.

2. One topic which is particularly suitable for elementary school science is the topic of balance, center of mass and torque. A superb activity in this topic is the mobile. Following detailed instructions and with guidance, the students design and build their own mobiles, and then explain in detail (using quantitative considerations) why the mobile is balanced. The students bring their mobiles to lab. The mobiles built by the students are generally excellent and use everyday objects, such as plastic straws, dowel rods or bamboo barbecue sticks. The students develop a very deep level of understanding of the physics by their hands-on experiences; they truly enjoy building their mobiles and being able to explain quantitatively why the balance condition is observed for each level of the mobile.

3. Each student is required to select, design, carry out and present a science fair project on a physics topic. Detailed instructions and guidance are provided to the students, and the projects are required to involve some quantitative experimentation (e.g., a qualitative demonstration would not be suitable). These projects are substantial, and involve much time and effort for the students. The students write reports on their projects, and present them in a mini-science fair scheduled during the lab. From their reports, I generate a handout for the students listing each student's project, with a brief description of each project.

I attend each lab section during science fair week, grade each presentation, read and grade each written report, and provide tangible prizes which are awarded (based on student votes) during each lab period. While this clearly involves a significant commitment of my time, the result is certainly worthwhile. Many of the students have never had the freedom to do a real science project, and blossom in this environment of creativity, originality and self direction. Many of the students are amazed to find that they truly enjoy doing science. Finally, many of the students recognize that they would probably be expecting their elementary students to do science fair projects, and yet, prior to this project, they had never fully realized what such a project entailed and how they would need to assist their students.

Grading Policies

The homework assignments and examinations involve a varied format, including quantitative problems (How far did the car travel?), qualitative comparisons (Which bulb is brighter?), qualitative problems (Draw a circuit in which the bulbs and switches have the following characteristics.), and brief essay questions (Explain how a fuse works and why it is important and describe two situations in which having an appropriate fuse would be critical.) Neither the homework nor the exams were computer-graded multiple choice. AIs were available to assist in grading the homework; the exams were graded solely by the faculty instructor.

During the spring, 1992 semester, the grading policy employed a fixed grading scale (A=90-100%, B=80-90%, etc., with + and - grades awarded within each grade level). The grades were based on the following:

30%	three in-class exams during the semester
20%	2-hour comprehensive final exam
15%	weekly homework assignments
15%	weekly laboratory assignments
15%	science fair project
4%	mobile project
1%	crystal project

A typical median score on the exams is 76%, and approximately one-half of the students receive grades of B- or better.

Conclusions And The Future

Q202 remains an extremely popular course among the students. The students generally leave Q202 with an excitement for physics, an understanding of several areas of physics, and a strong desire to teach physics in a hands-on way in the elementary schools.

One problem which has affected Q202 in the past has concerned the effectiveness of teaching in the laboratory sections, since Physics Department graduate students generally do not view physics in the conceptual manner that we stress in this course and are thus not well matched to the student population in Q202. This problem will be alleviated beginning in the fall, 1992 semester. I have invited all former Q202 students who received grades of B+ or better to apply to serve as lab instructors. While we do not have funds to pay our student-teachers, we will be giving them academic credit in P406: Physics Research.

I am delighted that in the upcoming initial semester, 19 former Q202 students will be teaching labs (scheduled at 2-4 teachers per lab section). This will be a superb experience for these student-teachers, as it will provide them with the experience of teaching and guiding the physics activities. It will also be excellent for the Q202 students who will experience a higher teacher-to-student ratio and will be able to better communicate with their instructors. I am excited about this new aspect of Q202, and anticipate it to be a grand success.

Finally I would like to acknowledge my colleagues in Science Education who have been instrumental in the evolution of Q202 over the years. Prof. Dorothy Gabel has continually provided me with much appreciated support (both moral and financial) in this work. Ms Betty Cordel (Science Education graduate student with an elementary teacher background) and Ms Karen Stucky (6th grade teacher and science coordinator of the local elementary school system) shared with me their wealth of experience in teaching elementary school science, and helped my confidence that our efforts in Q202 were correctly aimed. I especially wish to acknowledge the invaluable contributions of Mr. Michael Svec (Science Education graduate student) who has been working with me since the fall of 1990 on all aspects of Q202, and played an essential role in the implementation of computers and computer-aided laboratory activities.

Figure 1

Which velocity graph shows the object moving away from the origin at a constant velocity?

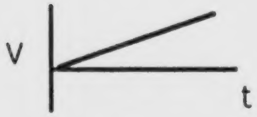
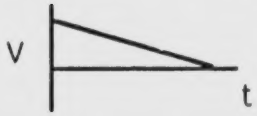
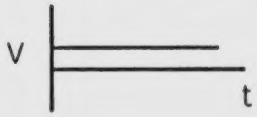
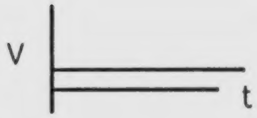
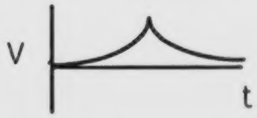
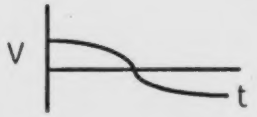
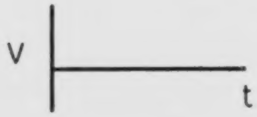
		Pretest	Post-test	
A.		75%	9%	
B.		4%	0%	
C.		18%	90%	<--
D.		0%	1%	
E.		0%	0%	
F.		0%	0%	
G.		3%	0%	

Figure 2

Which velocity graph shows the object reversing direction?

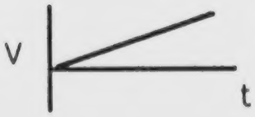
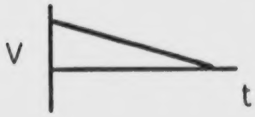
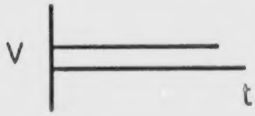
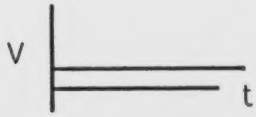
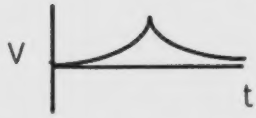
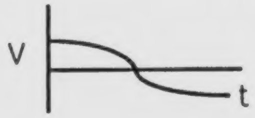
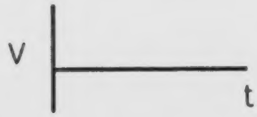
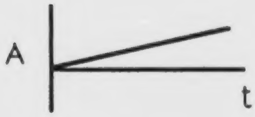
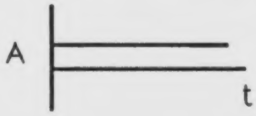
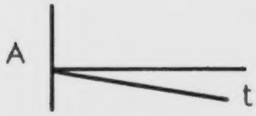
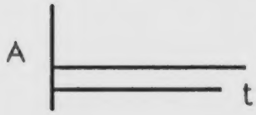
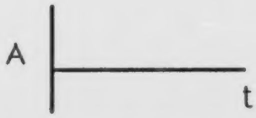
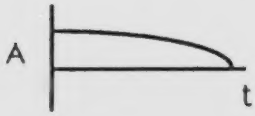
		Pretest	Post-test	
A.		0%	0%	
B.		9%	0%	
C.		0%	0%	
D.		0%	0%	
E.		65%	17%	
F.		22%	81%	<--
G.		0%	2%	

Figure 3

Which acceleration graph shows the object moving away from the origin at a constant velocity?

		Pretest	Post-test
A.		1%	1%
B.		11%	9%
C.		10%	5%
D.		33%	35%
E.		9%	47% <--
F.		10%	1%
G.	None of the above.	25%	3%

TEACHER KNOWLEDGE ISSUES

PANEL SESSION 2:
Developing Teachers' Pedagogical Knowledge

FACILITATING PRESERVICE TEACHERS' UNDERSTANDING OF MATHEMATICS AND SCIENCE INSTRUCTION IN AN EDUCATIONAL PSYCHOLOGY COURSE

Jeanne E. Ormrod and Kathryn F. Cochran
University of Northern Colorado

EXPERIENCES IN TEACHING TEACHERS DIFFERENTLY

Cherin Lee
University of Northern Iowa

ACHIEVING EFFECTIVE INSTRUCTION IN ELEMENTARY SCHOOL MATHEMATICS

Fredrick L. Silverman
University of Northern Colorado

DEVELOPING TEACHERS' KNOWLEDGE OF CONCEPTUAL CHANGE THROUGH CONTENT, SEMINARS, PRACTICUM, METHODS, AND STUDENT TEACHING

Joseph Stephans
University of Wyoming

FACILITATING PRE-SERVICE TEACHERS' UNDERSTANDING OF MATHEMATICS AND SCIENCE INSTRUCTION IN AN EDUCATIONAL PSYCHOLOGY COURSE

Jeanne Ellis Ormrod and Kathryn F. Cochran
University of Northern Colorado

An undergraduate educational psychology course is a required component of the teacher education program at the University of Northern Colorado. This three-semester-hour course includes coverage of learning and cognition, child development, motivation, classroom management, and assessment (i.e., testing and measurement).

In 1989 and 1990, two sections of the course were offered in conjunction with the university's NSF-funded "Pre-service Elementary Science-Mathematics Project." The purpose of this project was to conduct a model teacher education program through which future teachers develop additional proficiency in mathematics and science instruction and become especially aware of the ways in which the mathematics and science achievement of girls, minorities, and handicapped students can be fostered.

Rationale and Objectives

The educational psychology course was modified with several objectives of the "Pre-service Elementary Science/Mathematics Project" in mind:

- To increase the science and mathematics knowledge, critical thinking skills, and problem-solving abilities of pre-service elementary teachers.
- To prepare teachers to help their own students become informed problem solvers in science and mathematics.
- To increase teachers' confidence in "doing" science and mathematics and their ability to instruct pupils in these subjects.
- To enhance teachers' knowledge of barriers faced by underrepresented groups (e.g., girls, minority groups, physically disabled) in mastery of science and mathematics.
- To develop instructional strategies that help teachers overcome the barriers referenced in [the preceding] objective, thus enhancing the science and mathematics interests and abilities of underrepresented groups.
- To enhance teachers' views on relationships between science and mathematics, and on ways to coordinate the two subjects, thereby facilitating student science and mathematics learning.

Our revision of the course encompassed four general types of changes: (1) revision of course topics, (2) increased integration within the course itself, (3) increased integration of course content with other program courses, and (4) increased emphasis on application.

Revision of Course Topics

In accordance with project objectives, we increased coverage of the following topics:

Group differences. We identified differences among students that tend to be associated with particular genders, ethnic groups, socioeconomic conditions, and handicapping conditions. We specifically focused class attention on differences that are likely to affect students' achievement in mathematics and science, including differences in the following areas: (1) self-concept and self-esteem, (2) attributions, (3) sociolinguistics, (4) wait time, and (5) competition vs. cooperation. We also explored factors that lead to or exacerbate group differences, including factors at home, in school, in peer relationships, and in the media. Such concepts as socialization, modeling, gender schemas, and attributions played a significant role in our discussions. Finally, we examined cooperative learning approaches to classroom instruction, with particular consideration of how such approaches may facilitate the classroom performance of girls, minorities, and handicapped students.

Cognitive processes and developmental characteristics related to the learning of mathematics and science. We considered theories and research related specifically to children's ability to learn mathematics and science. Piagetian and neo-Piagetian research was examined with regard to the reasoning capabilities of elementary school children. We used information processing and constructivist approaches to consider how children learn concepts in science and mathematics. We explored some of the common misconceptions that elementary school children have with regard to scientific phenomena.

Alternative methods of assessment. We discussed "non-traditional" methods of assessing students' performance, with particular emphasis on how such methods can facilitate and measure higher-level cognitive skills. For example, we asked students to consider concept mapping, portfolios, and group-based assessments as potentially useful tools for assessing student learning and achievement.

Our increased coverage of the topics just listed necessitated a reduction in the coverage of other topics. We omitted a discussion of adolescence (since our students were preparing for elementary level teaching) and decreased our coverage of behaviorist approaches and traditional methods of assessment. Furthermore, we omitted many of the "nitty-gritty" details of what we traditionally cover, giving greater and more thorough attention to general concepts and principles (the "less is more" notion).

We found that, for our purposes, existing educational psychology textbooks did not adequately address group differences, cognitive processes and developmental characteristics related to the learning of mathematics and science, and alternative methods of assessment. Therefore, in addition to the required text (Glover & Bruning, 1990, *Educational Psychology*), we assigned a number of outside readings (see Table 1 at the end of this paper).

Increased Integration Within the Course Itself

Information processing and constructivist perspectives both point to the importance of *integration* of information in long-term memory. When students relate various ideas to one another as they store information, they are more likely to retrieve those ideas at times when they need them and more likely to apply them in new situations.

Two modifications of the course were specifically designed to foster increased inter-connections as students processed and learned course material:

Consistent use of information processing and constructivist themes. Several common themes ran throughout the course and were incorporated into our discussions of learning, development, motivation (especially attribution theory), and assessment:

- All knowledge is constructed.
- All information becomes organized.
- Working memory has a limited capacity.
- Long term memory has an unlimited capacity (as far as we know).
- Better organization allows better recall of information.
- Meaningful learning is connecting new knowledge to old.
- Prior knowledge determines what information is learned; therefore prior knowledge must be assessed.

Assignments requiring students to integrate course content. Assignments typically required students to pull together content from two or more topics covered. For example, one assignment asked students to develop ten separate ways to assess pupils' understanding, thus asking them to integrate their knowledge of information processing theory and assessment techniques. Another assignment asked students to explore differences between boys and girls in motives and attributions, thus requiring them to pull together motivation theory and gender differences.

Increased Integration of Course Content with Other Program Courses

In addition to the educational psychology course, students in the NSF project took the following courses:

Courses taken prior to Educational Psychology

- Earth Science Concepts for Elementary Teachers
- Equity Issues in a Technological Society
- Fundamentals of Mathematics I
- Effective Instruction in Elementary School Mathematics

Course taken concurrently with Educational Psychology

- Fundamentals of Mathematics II

Courses taken subsequent to Educational Psychology

- Physical Science Concepts for Elementary Teachers
- Teaching Science in the Elementary School
- Biological Concepts for Elementary Teachers

Faculty members teaching courses in conjunction with the project met once a month to share information about course content and to identify themes and concepts that could be incorporated into more than one course. As a result of our discussions, we were often able to build on students' previous coursework in the educational psychology course (thus facilitating integration of ideas *across* project courses). Here are some examples:

Discussing the idea that the study of teaching is a science. We explained how educational psychology and educational research share many characteristics of the physical and life sciences, including the scientific method, the need for control, and the need for an empirical base to theory development and educational practice. One of the assignments required students to conduct a small-scale research project (designing a questionnaire and interviewing children at several different grade levels).

Providing psychological explanations of gender and ethnic differences identified in the "Equity" course. Students took "Equity Issues in a Technological Society" in the semester immediately preceding the educational psychology course. The equity course was designed to sensitize students to group differences (those based on gender, ethnic group membership, and handicapping conditions) and to the importance of considering these differences in the design and delivery of classroom instruction. The educational psychology expanded on the group differences with which students were already familiar and considered the development of these differences from a psychological perspective.

Providing an information processing analysis of a geoboard activity previously utilized in the "Instruction in Mathematics" course. As a part of their "Effective Instruction in Elementary School Mathematics" course the preceding semester, students examined a "geoboard" activity as one example of a method of teaching the concepts of area and perimeter. In the educational psychology course, we were able to build on this previous knowledge. Project students reviewed and discussed the geoboard activity in small groups and then were asked to individually write two-to-three page papers describing and justifying the activity from an information processing perspective.

Describing the correlation coefficient in terms of the line of best fit. The notion of correlation is usually addressed in educational psychology in the context of measurement and assessment, particularly with respect to the importance of the reliability and validity of teacher-made and standardized tests. Because our students had all taken the same "Fundamentals of Mathematics" course the preceding semester, it was possible to introduce the concept of correlation within the context of material students had encountered in that course. The concept of line of best fit had been presented in the mathematics course, and the students' previous knowledge of this idea was used as a basis for discussing the uses (and abuses) of correlation in education.

Introduction of the learning cycle from an information processing context. Bybee's five-stage version of the learning cycle was briefly introduced as one of several examples of the direct application of learning theory to classroom practice. This strategy served two purposes. First, it allowed students to compare and contrast various approaches to lesson construction (e.g. the learning cycle and Hunter's model). Second, it revisited the earth science course that project students took their first semester in the program and prepared them for the science methods course to be taken the subsequent semester. Both of these courses were organized around the learning cycle.

Increased Emphasis on Application

Application of psychological theory to educational practice is an important component of any educational psychology course. In the project sections of the course, application was emphasized to an even greater degree than is traditionally the case. We increased our emphasis on application in four ways:

Making frequent connections between theory and practice. Theory and educational practice were taught concurrently; that is, theoretical notions were always presented with accompanying applications, and educational practices were always described in terms of their theoretical underpinnings. An assignment described earlier, in which students were asked to justify a geoboard activity from an information processing perspective, is an example of how we continually tied theory with practice.

Team teaching with a "mentor teacher". Project funds provided for a practicing elementary or middle school mentor teacher to team-teach the course with us (in one case he was a fifth-grade teacher; in the other case he was a middle school science teacher). The mentor teachers were our partners in teaching the course and provided invaluable "real classroom" applications and examples of course content.

Application of course content to how we taught the course. In particular, we modeled a variety of teaching methods that promote effective long-term memory storage processes (such as meaningful learning and elaboration). During expository instruction (i.e., lectures), we incorporated such pedagogical tools as advance organizers, in-class questions, and study guides. We also modeled other approaches to instruction, including structured group discussions, cooperative learning (e.g., semester-long base groups), and hands-on activities (e.g., solving problems involving formal operational reasoning; demonstrating the scale of the solar system by asking students to act as "planets" and stand in relative distances from the "sun" [Mercury stood a foot away from the sun, while Pluto stood a half block away]).

Using (and thereby modeling) assessment techniques that promote meaningful learning and elaboration. Course grades were based on both application-oriented assignments (40%) and application-oriented examinations (60%). We incorporated incentives for cooperative learning into our assessment criteria; more specifically, we assigned group projects, incorporated "cooperative group essays" into examinations (whereby students discussed a question for five minutes, then separated to write their individual responses to the question), and gave bonus points to each group member when the group's average exam score reached a certain level.

Assignments emphasized the application of theory to classroom practice. In the first section of the course we assigned a "microteaching" activity in which students: (1) developed a lesson plan for teaching a topic in mathematics or science based on information processing principles, (2) delivered the lesson to their peers, and (3) analyzed their own (videotaped) performance according a number of criteria related to instructional effectiveness (an evaluation form was developed for this purpose by our colleague, Dr. John Cooney; the form was adapted from that of H. J. Freiberg [1987] in the *NASSP Bulletin*, *71*, pp. 85-92). In the second section of the course, we assigned a number of smaller projects, in almost every case asking students to provide theoretical justifications for the instructional practices they described.

Exams typically consisted of both multiple-choice-with-rationale items (in which students had to defend their answers in one or two sentences) and essay questions; two examples are presented below:

Multiple Choice with Rationale

Which of the following is an educational implication of working memory?
- a. Students can remember information only if it is unconnected.
- b. Teachers should not present too many new ideas at one time.
- c. It allows students to learn with great speed.
- d. Teachers should present information using only one sense, such as vision.

RATIONALE:

Cooperative Group Essay

Piaget described a number of weaknesses of the preoperational child--things that concrete operational children can do, but that preoperational children cannot. Identify and describe three weaknesses of preoperational children that will interfere with their ability to learn math and science. Be specific about the math- and science-related things that preoperational children may be unable to do as a result of each weakness.

Effectiveness

The evaluation component of the project included a comparison of project sections with "control" (i.e., more traditional) sections of educational psychology. Project students were able to identify a greater number of applications of psychological theory to classroom practice; their applications were also more concrete and specific. Our own informal observations indicated that, in comparison with students in traditional sections of educational psychology, students in the project sections were more aware of the interrelationship between theory and practice, more confident about their ability to teach mathematics and science in an elementary school classroom, and more sensitive to the particular needs of girls, ethnic minorities, and handicapped students.

We should briefly mention some minor problems we encountered during course delivery:

- Insufficient class time for adequate coverage of all topics.
- Additional time necessary for class preparation and in grading assignments and exams (in comparison with traditional sections of the course).
- Some student resentment of grades being partially based on base group performance.

Recommendations

Our formal and informal assessments indicated that the course modifications we have described enabled us to meet project objectives. We believe that the following components were instrumental in the success of the course:

- The increased emphasis on relationships between theory and practice.
- The incorporation of certain themes throughout the course.
- The coverage of fewer ideas in greater depth ("less is more").
- The contributions and the expertise of the mentor teachers.
- The monthly meetings with faculty teaching other program courses.
- Commitment of the university to cooperation between the College of Education and the College of Arts & Sciences.

Table 1. Assigned Readings for the Educational Psychology Course

Anderson, C. W. (1987). Strategic teaching in science. In B. F. Jones, A. S. Palincsar, D. S. Ogle, & E. G. Carr (Eds.), *Strategic teaching and learning*. Association for Supervision and Curriculum Development.

Bem, S.L. (1983). Gender schema theory and its implications for child development: Raising gender-aschematic children in a gender-schematic society. *Signs: Journal of Women in Culture and Society, 8*, 598-616.

Carey, S. (1986). Cognitive Science and science education. *American Psychologist, 41*, 1123-1130.

Casanova, U. (1987). Ethnic and cultural differences. In V. Richardson-Koehler (Ed.), *Educator's handbook: A research perspective.* New York: Longman.

Cordua, G. D., McGraw, K. O., & Drabman, R. S. (1979). Doctor or nurse: Children's perceptions of sex typed occupations. *Child Development, 50*, 590-593.

Fennema, E. (1987). Sex-related differences in education: Myths, realities, and interventions. In V. Richardson-Koehler (Ed.), *Educator's handbook: A research perspective.* New York: Longman.

Heath, S. B. (1980). Questioning at home and at school: A comparative study. In G. Spindler (Ed.), *The ethnography of schooling: Educational anthropology in action.* New York: Holt, Rinehart, & Winston.

Hofwolt, C. A. (no date). Instructional strategies in the science classroom (pp. 43-58). In D. Holdzkom & P. B. Lutz (Eds.), *Research within reach: Science education.* Washington, DC: National Science Teachers Association.

Johnson, D. W. & Johnson, R. T. (1975). *Learning together and alone: Cooperation, competition, & individualization* (Chapter 1). Englewood Cliffs, NJ: Prentice-Hall.

Kahle, J. B., & Lakes, M. K. (1983). The myth of equality in science classrooms. *Journal of Research in Science Teaching, 20*, 131-140.

Marzano, R. J. & Costa, A. L. (1988, May). Question: Do standardized tests measure general cognitive skills? Answer: No. *Educational Leadership*, 66-71.

Montemayor, R. (1974). Children's performance in a game and their attraction to it as a function of sex-typed labels. *Child Development, 45*, 152-156.

Murray, C. B., & Jackson, J. S. (1982/83). The conditioned failure model of black educational underachievement. *Humboldt Journal of Social Relations, 10*, 276-300.

Novak, J. D. & Gowin, D. B. (1984). *Learning how to learn* (Chapters 1 and 2). Cambridge, England: Cambridge University Press.

Resnick, L. B. (1989). Developing mathematical knowledge. *American Psychologist, 44*, 162-169.

Ruggiero, V. R. (1988). *Teaching thinking across the curriculum* (Chapter 8). New York: Harper & Row.

Shields, P. M., & Shaver, D. M. (1990, April). *The mismatch between the school and home cultures of academically at-risk students.* Paper presented at the American Educational Research Association, Boston, MA.

Stipek, D. J. (1984). Sex differences in children's attributions for success and failure on math and spelling tests. *Sex Roles, 11*, 969-981.

EXPERIENCES IN TEACHING TEACHERS DIFFERENTLY

Cherin Lee
University of Northern Iowa

One of the major foci of the Preparation of Elementary Mathematics and Science Teachers (PEMST) project at the University of Northern Iowa is to teach future teachers differently. The undergraduate content and methods courses are arranged to maximize the use of pedagogy by college faculty in teaching the respective science disciplines. An example of this is the Experiences in Elementary School Science course, nicknamed E^2S^2 by students. This course is a three credit hour course bridging content courses and science teaching methods courses. Experiences in Elementary School Science offers a heavy field experience component in which the students use science content and process and the learning cycle approach to teaching, all learned through a three course segment of their science minor (see Figure 1).

The E^2S^2course fits into the Basic Science Minor and the Elementary Education major as shown in Figure 2. It is basically a third level course in the minor. The first level courses, Activity Based Physical Science and Activity Based Life Science, are four credit hour courses that integrate laboratory and lecture in a non-formalized way. There is no set lecture or laboratory day. The schedule is flexible and set for each content unit as to which class periods will be lecture and which laboratory. There is no minimum or maximum amount of time devoted to either presentation mode. Thus, the needs of the students and the content drive the of time spent in laboratory and lecture.

Though both courses are laboratory-oriented and, activity-based, they are not conceived in a learning cycle format. However, students always "do before they talk" and thus the lectures are based on experiences garnered by students during their laboratory activities.

In contrast, the second level of content courses, the three Investigations courses, are all taught in a three-part learning cycle format. Investigations in Earth Science, Investigations in Physical Science and Investigations in Life Science are all four credit hour courses meeting for five contact hours per week. They use an exploration, concept development, application format (see Figure 2).

Upon completion of this five course content core, science minors have 20 hours in content in the basic sciences of biology, chemistry, earth science, and

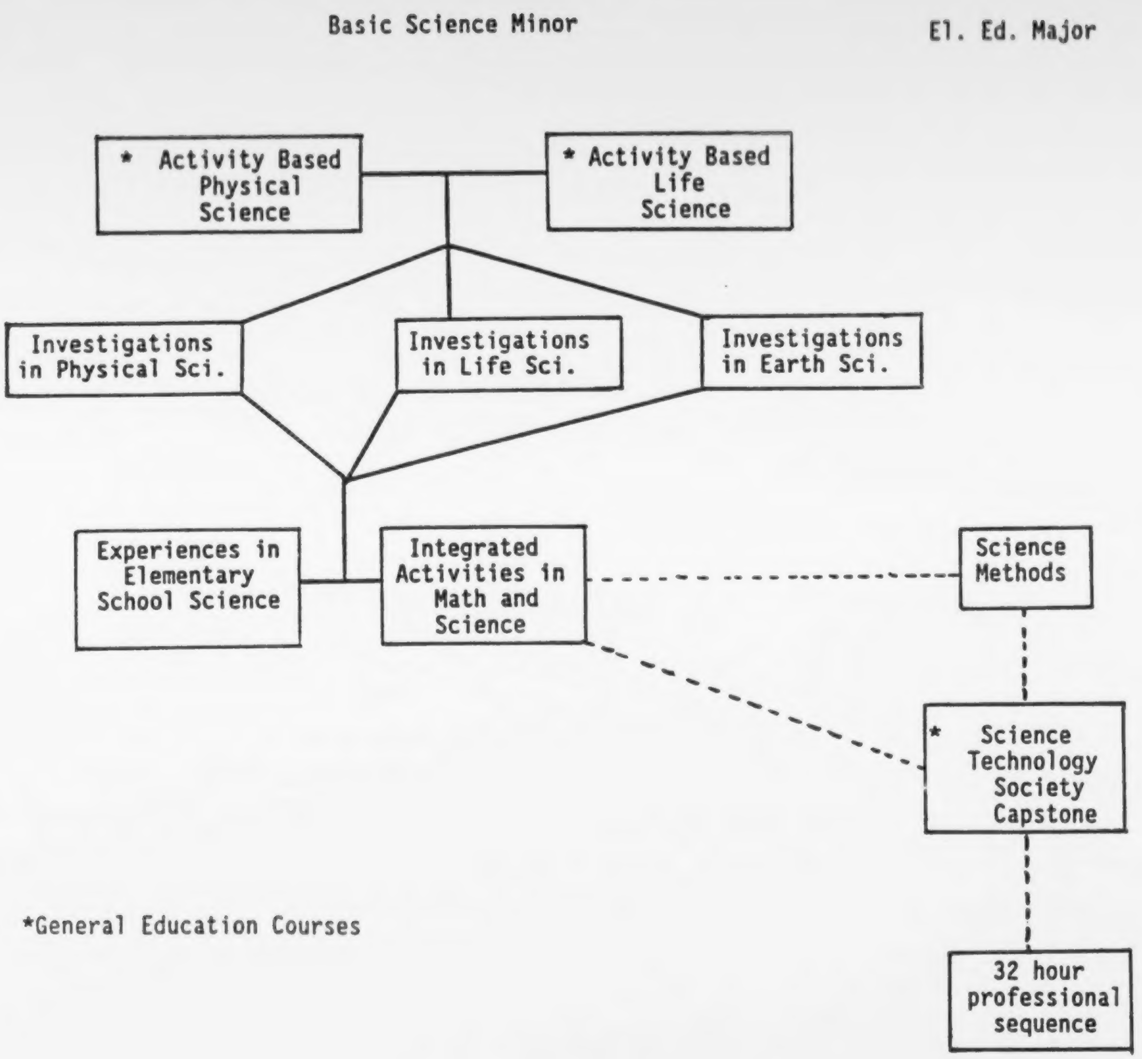
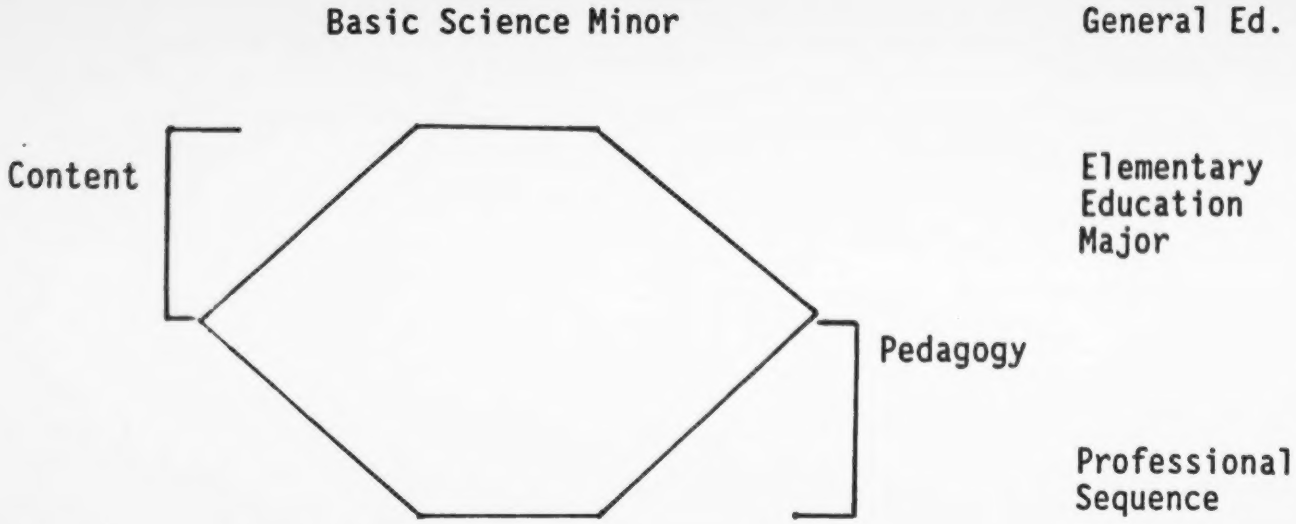

Basic Science Minor
El. Ed. Major
* Activity Based Physical Science
* Activity Based Life Science
Investigations in Physical Sci.
Investigations in Life Sci.
Investigations in Earth Sci.
Experiences in Elementary School Science
Integrated Activities in Math and Science
Science Methods
* Science Technology Society Capstone
32 hour professional sequence
*General Education Courses

Figure 1

Outline of the Basic Science Minor for Elementary Education Majors

Program Context



Content courses: Teach content and model pedagogy

Methods courses: Teach pedagogy and apply content

Content - Activity Based approach

- Learning Cycle approach

Methods - Capitalizes on above

Figure 2
Relationship between Content and Pedagogy

physics. A student in E^2S^2 must have had both Activity-Based courses plus two of the Investigations courses. Thus E^2S^2 students have a minimum of 16 hours of content, all of it experiential in nature, and eight hours of it taught via the learning cycle.

Students at this stage have experienced content courses that teach science content and process and model pedagogy. Experiences in Elementary School Science teaches pedagogy and applies science process and content, capitalizing on students' experiences in learning. It should be pointed out that many of them are learning in a different way then previously experienced throughout their education. This enables E^2S^2 to work on pedagogical knowledge, not just teaching methods and neat activities.

Experiences in Elementary School Science includes a constructivist perspective on how children learn, taught by a science educator. This helps the preservice teachers focus on their science learning experiences and also leads to a more specific understanding of how elementary students learn science. This creates a bridge from learning to teaching. E^2S^2 uses *The Learning Cycle and Elementary School Science Teaching*, by Renner and Marek plus a module, *Teaching and Thinking*, by Barman and Cooney (see Figure 3).

Students next review the Iowa state curriculum guidelines to identify concepts and processes recommended for elementary science at various grade levels. Based on this, each student writes a learning cycle lesson, peer teaches the lesson and has it videotaped for analysis. After analysis and possible redesign, the learning cycle lesson is taught to students in a local elementary school. This latter experience is part of the heavy field experience component of the course.

Two other opportunities for field experience occur before the teaching of the student-constructed learning cycle. E^2S^2 students spend time observing teacher style, instructional design, classroom management, teaching strategies and student-teacher responses. A heavy emphasis is put on questioning as a teaching strategy. Next, the preservice teachers teach elementary students an exploratory activity. This stresses introducing and starting a lesson, plus questioning and teacher-student relationships. This is videotaped and evaluated. The teaching of the student-constructed learning cycle is the last segment of the field experience component. This is a full lesson, comprising at least three consecutive class periods.

A unique aspect of the course is the introduction of area teaching resources. Such non-school resources for teachers as museums and nature

E^2S^2 in brief:

. overviews constructivist perspective on learning

. identifies concepts and processes for elementary grades

. writes and teaches science lessons - learning cycle approach

. introduces area teaching resources

. field experience component
    1) observing
    2) exploratory lesson teaching
    3) full learning cycle lesson teaching

Figure 3

Experiences in Elementary School Science: Course Overview

centers are overviewed and visited. Then students participate in two ways in one of the programs in the metro area. First, they shadow one of the people working with school programs in a museum or nature center. Then they are involved in conducting a learning experience for elementary children in the museum or nature center.

Experiences in Elementary School Science has been taught once, undergone some revisions, and is currently being taught this fall for the second time. The course is taught by someone on the science education faculty, which at UNI is someone in the College of Natural Sciences. This faculty person's comments show how much can be learned from redesigning a course and trying to practice what we know about learning and teaching science. The idea of merging content and pedagogy in a content-specific format seems to be very beneficial and is in fact a necessary transition from content to teaching. The professor finds that E^2S^2 is necessary, even if the students have learned their science via the learning cycle approach (see Figure 4).

Teaching this course has made it clear that good learning cycle lessons are not easy to write. Those of us using learning cycles for years have labored with this and it appears that even after learning from this vantage point, it is still not easy to create cogent learning cycle curricula. Points to emphasize are 1) explorations that really create student experiences, 2) questioning rather than telling, and 3) applications that are pertinent and connected to the lesson as a whole.

Difficulties in the course are mostly in the area of the field experience component. Logistics and administration of field experiences is difficult. Such experiences must be local, in the metropolitan area surrounding the university. However, with a large teacher education program such as exists at UNI, the university laboratory school is overloaded, necessitating use of community schools. Some of these schools are also rapidly approaching a saturation point. Supervising the field experiences is also difficult, particularly with students spread all over the metro area. Visitations can be replaced by videotaping the experiences, but we have found, that contrary to popular belief, not all schools have video equipment ready at hand, nor someone to operate it. One solution is to train the preservice teachers and let them practice using video equipment during their peer teaching in class and then send them to schools in pairs so that one can teach and one can videotape. Finally, meaningful evaluations of the field

Comments:

. merges content and pedagogy

. reflects on student learning (own) and bridges from content to teaching

. good learning cycle lessons are not easy to write/teach

. logistics and administration of heavy field component is difficult

. meaningful supervision and evaluation of field component is difficult

Figure 4
Instructional Comments on E^2S^2

experience takes time. It also holds the challenge of determining what is meaningful in the way of evaluation.

No doubt the course will continue to evolve. Much has been learned in the first two offerings and the fine-tuning is about to begin. Student responses show their patience with course re-design and also their enthusiasm for a course that actually enables them to learn about teaching science. They get to use what they know, and they also know what they use.

ACHIEVING EFFECTIVE INSTRUCTION IN ELEMENTARY SCHOOL MATHEMATICS

Fredrick L. Silverman
University of Northern Colorado

Introduction

I remember back in 1968 when I was a graduate student at the University of Chicago. I was working on a Masters of Arts in Teaching of Mathematics, and I had occasion to learn some algebra from Professor Saunders MacLane. He was a mathematician interested in being a competent and entertaining teacher. One of the anecdotes he told was a story of a former professor of his during his own graduate studies. I believe it was Professor Landau. Landau had just finished presenting to his class a proof of the Fundamental Theorem of Algebra.

From the back of the room Landau recognized a student who had raised his hand. "From about the middle of the third board," he said, "to the end of the eighth I just don't follow the proof. Could you help me understand that part of the proof?" he asked.

Landau paced briefly and then had MacLane erase the chalk board. Then the great professor went through every detail of the proof a second time, just as he had done the first, this time, however, really projecting his voice to the rear of the lecture room. When he finished, Landau asked the student still had difficulty with the proof of the theorem.

"Yes, Sir," he said, "I do. I still just cannot follow the reasoning from about the middle of the third board to the end of the proof."

Landau was distressed, obviously disappointed with himself, according to my recollection of MacLane. "I guess I'm still not talking loud enough," Landau shouted, and then he proceeded to present the proof again.

Reflection

To his credit, Professor Landau recognized he needed to change his approach to this proof to assist the understanding of his student in the back of the room. But, for all his good intentions, Landau merely raised the volume of his voice. Now sometimes failure to understand is a result of hearing deficiency, but in this case Landau needed to do more than simply turn up the sound. He needed, for instance, to adjust his words, use questioning or Socratic dialogue, show some examples using more familiar arithmetic or algebra, or display some graphical representation. Such moves would have indicated a much more sophisticated level of pedagogical content knowledge on Landau's part.

Insights from three sources combine to create pedagogical content knowledge in general: psychological development, instructional approaches, and content of a discipline. When the focus of psychological development is on construction of mathematical concepts, and when the focus of instructional approaches is on those pertinent to learning mathematics, and when the subject matter is mathematics, then the knowledge one gains is pedagogical content knowledge for teaching and learning mathematics. The course, EDEL 420, *Improving Instruction in Elementary School Mathematics*, is designed to facilitate acquisition of pedagogical content knowledge in the area of mathematics for those who are prospective elementary school teachers. To that end, the following knowledge base statement was presented:

> This course on mathematics education focuses on increasing the prospective teacher's level of pedagogical content knowledge. From knowledge of mathematics content, generic instructional strategies, and learners' cognitive and affective profiles, classroom teachers make choices for optimizing pupils' learning. The EDEL 420 instructor, through modeling and direct instruction, provides on-campus and field experiences that promote appreciation of problem solving, social participation in learning, diverse instructional strategies, and professional reflection.

The intent of this course is for prospective teachers to address the learning and teaching of mathematics using the solid three-legged-stool stance in which the legs are knowledge of students, knowledge of instructional strategies, and knowledge of mathematics.

Direction of the Course

A grant from the National Science Foundation provided the opportunity to recast a number of courses in the teacher education program, among them this mathematics education course. The goals reflect commitment to mathematics as a vibrant discipline open equally to all people and determination to certify thoughtful, professional entry teachers. The goals for the course are as follows:

- Preservice teachers will acquire competence in guiding the mathematical education of elementary school students.

- Preservice teachers will cultivate a systematic application of reflective decision making in promoting the mathematical education of elementary school students.

- Preservice teachers will value and act upon the belief that mathematics is a dynamic discipline, one in which all young people can participate as creative and successful learners and one which opens societal opportunities regardless of race, gender, religion, handicap, or national origin.

These goals focus attention on mathematics as an active discipline. They encourage prospective teachers to make instructional plans based on their best knowledge of learners, mathematics content, and pedagogy. They underscore the importance of professional reflection on the effectiveness of mathematics learning experiences that teachers implement.

The following are specific objectives that are compatible with the goals:

1. To become familiar with the scope and sequence of elementary school mathematics
2. To become familiar with cognitive development, as exemplified in Piagetian and constructivist theories, and to understand implications of those theories
3. To become familiar with selected resources for mathematics instruction
4. To understand the role of problem solving in school mathematics
5. To understand the concept of "drill and practice at the problem solving level"
6. To understand that "mathematics is a search for relationships that are not obvious"
7. To become familiar with a learning cycle approach to mathematics instruction
8. To cultivate sensitivity to equity and affective issues
9. To supplement traditional approaches to mathematics instruction
10. To organize and implement mathematics with elementary children
11. To develop awareness of calculators and computers in school mathematics
12. To encounter integration of mathematics with other subject matter

objectives promote problem solving, a broad view of the discipline, empowerment of students and teachers, and an inquiring mentality. This approach contrasts sharply with traditional encounters with mathematics that are as common among prospective teachers as they are among most other members of contemporary society in the United States.

I recall asking a fourth grade teacher not long ago about her approach to mathematics, given so many creative programs available for inservice professional growth. "Take multiplication," she said. "I believe in the old way to teach it. I use flashcards so they learn the facts." In contrast, however, I want prospective teachers who take this mathematics pedagogy course forever to realize that mathematics is so much more than flashcards and arithmetic, and who know that "mathematics," as expressed by Robert W. Wirtz in *Mathematics for Everyone*, "is a search for relationships that are not obvious."

Among the tenets guiding this project is the one that impels all course instructors to model strategies that are transportable to elementary school classrooms. Each and every one of the laboratory lessons affords opportunity for preservice teachers to engage in activities that will lead to effective mathematics learning experiences with children. While adaptations of depth, pace, and reflection are necessary for such pedagogical mobility, the processes of inquiry, construction, handling of material, and social interchange are authentic in each setting.

A mathematics laboratory on use of geoboards for exploring geometrical concepts and ideas along with graphing provides an effective example. The lesson is an adaptation of one developed by Marilyn Burns and described in an issue of *The Math Solution Newsletter*. Preservice teachers work in cooperative groups. First, they have a time for play and free exploration with geoboards and rubber bands. For many of the students this encounter is their first with these mathematical materials. They find all sorts relationships and mathematical artifacts in the free play. Second, I have students discuss in their groups mathematical concepts that emerged in the free play. One member takes notes, perhaps as they explore, of the concepts that emerge. Symmetry, area, perimeter, counting, patterns of all sorts, various polygons, and still others occur on the lists. Students write those lists on the chalk board, and a member of each group narrates the group's list. This approach leads to worthwhile discussion, and students often reveal surprise that so many geometric concepts permeate the free play at a subtle level. This search for concepts also helps students connect the use of geoboards with standard school mathematics objectives, targets of mathematics instruction that traditional approaches address almost exclusively in drill and practice. Third, after the discussion I have students clear their geoboards. The prospective teachers are about to take a turn into graphing that none of them suspect.

Their task is to use the material to create a dwelling of some kind. I keep the directions a bit vague because I am interested in variety. I tell them, "A dwelling is a place where a critter of some kind lives." They get the idea that people and other critters, as well, live in dwellings. After a few minutes of thinking and construction, each prospective teacher has a dwelling on her geoboard. Representations have included, but have not been limited to, the following: teepee, recreational vehicle, igloo, houseboat, townhouse, ranch house, two-story house, cave, nest, rock, beehive, church, and spaceship. I have students draw their dwellings on dot paper that is about the same size as the geoboards they used. Once the class gets a feel for the variety of dwellings, they tape their drawings over labels I prepare for each type of dwelling. In that way the class creates a bar-like graph of their dwellings. Fourth, a couple of students and I make a few example observations about the graph. Then each student and I make a small representation of the graph on a piece of typing paper and write one observation each about the graph.

When everyone completes that job, it's time to share again as a whole class, and the discussion is lively. Class members' observations are like these:

> There are twelve types of dwellings on the graph.
> The dwelling that has the most of a kind is the two-story house.
> There are just as many igloos as there are recreation vehicles.
> One-third of the dwellings are animal homes.
> All of the two-story houses are made up of rectangles and triangles.

These observations enable students to consolidate their activity through language. The language is message oriented, rather than social, and peers can check the validity of each statement for themselves. The language builds context. The communication leads to new insights for every student. The activity relates several strands of the mathematics curriculum, including geometry, graphing, statistics, and arithmetic. Such connections rarely characterize traditional approaches to school mathematics. The lesson is empowering and provides every student opportunity for mathematical success and learning.

After the group time for sharing observations about the graph, I collect each class member's sheet. I staple them together with a cover sheet to create a class book, which class members pass around. The reading, writing, and mathematics connections are especially noteworthy because these students are also taking a reading education course. In an elementary school, children can create and read many such books over the course of a year. In that way the youngsters have many reflections on mathematics lessons after the lessons have been completed.

This lesson affords prospective teachers plenty of opportunity to reflect on the pedagogical content knowledge of the teacher who would choose this type of encounter, it gives them opportunity to think back over their own participation and discern the role of the student, and it gives them a chance to elaborate on the role of the teacher in a classroom predicated on construction of mathematical knowledge. Finally, I show them slides of my leading this same lesson with second and third graders at the Laboratory School at the University of Northern Colorado. That culmination demonstrates the sheer and striking transportability of this lesson and adds enormous authenticity to the mathematical and pedagogical experiences that this class offers. Students vividly remember such events when they are planning mathematical lessons during their cadet teaching, the field part of this course.

In another geoboard investigation, students find areas of triangles and some odd-shaped polygons. The lesson is devised so that students develop the procedure of breaking up the interior region into parts whose areas are easy to determine. The final example is a triangle with no sides parallel to an edge of the geoboard. Such a triangle does not succumb to the same area determination procedure as did those that appeared previously. The pedagogical choice of such examples that depend on contradiction is substance for class consideration. In Piagetian language I tend to say that students assimilated each example with relative ease until the need to accommodate to a different situation arose. That experience also is a point of reference that prospective teachers subsequently encounter again when they study educational psychology. The connection between this mathematics pedagogy course and the educational psychology course is a profound one for the deeper study of Piagetian theory and contemporary ideas on construction of knowledge.

One other class activity is particularly important for its mathematics and science connection. The Bean Launcher Lab challenges class members to build an eclectic, unlikely inventory of materials a machine that will propel a bean as great a distance as the class member inventor can achieve. Materials available include thumbtacks, straws, paper cups, rubber bands, tongue depressors, and string. Prospective teachers build and test their machines and then make adjustments to enhance functioning. They measure the distances their machines propel beans down an inside corridor or outside along the sidewalk with meter sticks. I set up a computer with loaded a spreadsheet, and students log in data for their three trials. With the aid of a printer every member of class gets a set of data to study. I have each student compute an arithmetic average, and I have the spreadsheet program do the same. That way, students often catch errors, or else they may explore discrepancies that occur because of different rounding procedures. As a class, we study trends in the data and summarize the performances of machines and inventors. We try to explain factors that contributed to performances of the various launchers. Students also classify launchers according to type of machine. Among the types that have occurred are these: catapult, bow and arrow, sling shot, hockey stick, and pea shooter. This lesson is beneficial for several reasons, among which are the mathematics and science connections and the support of the equity commitment within the NSF-funded project. The commitment to equity is evident in that so many young women have had such limited experience with construction of this sort. Modeling the natural use of computing technology is a boon for everyone in the class, where so few have had the technology so unobtrusively available to them.

When I taught this class within the context of the NSF Project, all but 20 percent of the assessment came from labs, field experiences, home writing, and the like. The other 20 percent was from conventional multiple choice examinations. In the academic year since the second wave of project students completed this course, I have experimented to assess student accomplishment without formal examinations at all. Students complete two projects depending on their own personal interests and choices. I have had prospective teachers develop a variety of projects, among which are the following:

- mathematics and language lessons based on children's literature,
- counting and rhyming songs from different cultures,
- reports of attendance and participation at a state mathematics conference,
- development of integrated learning activities for mathematics and geography, and

- use of games for teaching and learning mathematics.

I have appreciated the conscientiousness with which students have accomplished their personally-selected projects. I prefer the personal sense of empowerment and dedication that comes with such activity, and I am pleased I took that step for performance assessment. Had it not been for the project, I am confident I would have had to devote more time to develop my personal level of confidence in alternative assessment.

The project course was faithful to the NCTM standards, as is its successor course. I have chosen not to emphasize the NCTM standards very much explicitly. Prospective teachers learn that this professional society has developed and promoted two volumes of standards, but I reserve the actual requirement of direct experience with the standards for graduate students. Instead, I work conscientiously to conduct a class for prospective teachers that is compatible with the standards. The greatest weakness in this course, confirmed by student reports and interviews, has been in the area of management of time to try to accomplishment all that I have packed into the objectives. My goal has been to do the best I can in the face of a tight schedule and my acceptance of students' general need to explore mathematical ideas and the instructor's responsibility to model transportable strategies and values. Hence the course puts a premium on exploration, high engagement, problem solving, use of manipulative materials, integration, connection, and field experience. Students' evaluations indicate their greater likelihood to use alternatives to abstract teaching of mathematics, their attitudes no less positive at the end of the course than at the beginning, their appreciation of the use of cooperative learning, their valuing of problem solving, and their strong endorsement of the field experience component.

These prospective teachers look like strong candidates for elementary school mathematics and science teaching. My experience with them and this project has been personally rewarding and full of professional growth.

DEVELOPING TEACHERS' KNOWLEDGE OF CONCEPTUAL CHANGE THROUGH CONTENT, SEMINARS, PRACTICUM, METHODS AND STUDENT TEACHING

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Rationale and objectives

The intent of the project at the University of Wyoming was to develop and test a model for improving preservice science education for elementary teachers. The components of the project consist of content courses, parallel seminars, methods, practicum, and student teaching. The content courses provide prospective teachers with the knowledge background. The seminars help them make connections between what they are learning to what they will teach. During the practicum prospective teachers interview children and observe teachers teach science using the strategies. The methods course provide our students the opportunity to apply what they have learned in the content and the seminar to an elementary classroom. Finally, during student teaching prospective teachers, with the support of mentor teachers, design and teach appropriate lessons to children.

Throughout the project we have tried to give our prospective teachers the opportunity to develop the skill of identifying children's naive ideas in science and to learn approaches they can use in helping children to overcome those naive ideas. Therefore, one of the teaching strategies we selected for our project was teaching for conceptual change--a modified learning cycle strategy. Our objectives for this part of the project included the following:

- Help prospective teachers to become aware of their own perceptions related to a concept and those of others;
- Develop knowledge and skill in identifying children's preconceptions;
- Develop skills in creating learning environments to bring about conceptual change in children;
- Become knowledgeable about research in the area of teaching for conceptual change.

Approaches

As our colleague David Hawkins has said repeatedly and as Rodger Bybee stated in his address to us in Greeley, *the notion of conceptual change is a slow and evolving process.* Our prospective teachers, we have felt, should experience first hand *what it* feels like to go though a conceptual change. Therefore, in our content courses and the parallel seminars they are placed in situations to experience this as they learn *new* science concepts. In the seminars, methods, practicum and student teaching, our prospective teachers experience strategies which may be conducive to bringing about conceptual change and learn to create similar environments for their children. In addition, prospective teachers in the project become familiar with relevant literature in areas such as: interviewing, identifying and dealing with children's misconceptions, and the examining the effectiveness of teaching for conceptual change strategies.

Some of the key elements of the program are illustrated in Figures 1-3 at the end of this paper. Figure 1 is an example of the relationship between the activities and experiences in the content course, parallel seminars and the practicum. Figure 2 is a brief outline of what happens in the methods course. It should be mentioned that during the methods course, our students spend about 1/3 of the semester either talking with children to identify their perceptions of science, observing teachers use cooperative learning and teaching for conceptual change or teaching children science units they have prepared. Figure 3 outlines the steps involved in the interview activity.

Outcomes/Effectiveness of Approach

Almost all the students in this project rated the practicum experience with a mentor as very profitable and an important element of the program. Even if they felt they were placed with an ineffective teacher, they still maintained that the practicum was vital. Students indicated that peer coaching was also beneficial. Comments such as "I felt I learned the teaching strategies when I was coaching" or "feedback from the mentor on the coaching forms helped improve the next lesson" are indicative. Several students felt that they did not do enough coaching and suggested making it a requirement.

The seminar activities taken parallel to each of the content courses were mentioned as valuable when planning and teaching in the classroom. Representative comments include "I learned a lot of content in seminars"; "We used several activities straight from the seminar and they worked great"; or, "The program has made me, through seminar in particular, to know what I need to do and get my priorities straight."

Interviews with students revealed the positive impacts of the use of interviews with children , cooperative learning and teaching for conceptual change instructional strategies, questioning strategies, and exposure to the resources and materials available to them for classroom teaching. The majority of the students expressed a much higher level of confidence toward their ability to student teach. Illustrative comments include "At first I was scared but as time went on I found I could do it." "The experience helped me relax" or "Now I feel ready to go teach".

Perhaps the most telling comments centered on the students expressed feelings regarding science. Following are examples: "I never thought science would be my strong area"; "I feel great about science"; "I used to hate it and was scared - now I enjoy it so much that I am looking forward to teaching it"; or, "I feel confident about teaching science although I am somewhat apprehensive about how to teach the other subjects."

Recommendations

In preparing teachers one needs to look at the entire picture and examine all the components and their connection to each other. Prospective teachers need to experience first hand the feeling of conceptual change as they learn new science concepts. They should gain the skill of interviewing children to determine children's science perceptions. They need to become familiar with the activities and approaches appropriate for elementary children which may bring about meaningful changes in children's perceptions. However, one needs to keep in mind that the *process of conceptual change* evolves slowly. This is true for children as well as adults.

In the methods and student teaching phases of the project, prospective teachers should spend considerable time observing teachers use this conceptual change model with children, develop and teach appropriate units to children using the model and keep track of the changes brought about in children as a result of these experiences.

CONTENT	SEMINAR	PRACTICUM
Matter and its properties	**Use teaching for conceptual change/cooperative learning**	
*Physical & chemical properties *Density *States of matter	*Mystery powders *Ice cubes *Mixtures & solutions *Change & measurment	*Interview students *Observe mentor teachers use conceptual change and cooperative learning in teaching topics of matter

Figure 1

Relationships between Program Components

Content of the Methods Course

- Observe Mentor Teacher
- Interview students and determine preconceptions
- Design lessons based on preconceptions
- Teach lessons (unit) coached by Mentor Teacher
- Study conceptual change in children
- Other issues:
    - *Misconceptions
    - *Questioning
    - *Curriculum analysis
      (BSCS, ESS, SCIS, FOSS, OBIS, AIM's . . .)
    - *Gender issue in science classroom
    - *Evaluation

Figure 2
Contents of the Methods Course

Steps Involved in the Interview Studies

- Choose a concept
- Select students
- Prepare questions
- Think about follow-up questions
- The interview setting
- Compile responses
- Review textbook
- Review appropriate literature
- Synthesis
- Implications to learning/teaching

Figure 3
Steps Involved in The Interview Studies

TEACHER KNOWLEDGE ISSUES

PANEL SESSION 3:
Developing a Cohesive Program

THE DEVELOPMENT OF A COHESIVE SCIENCE EDUCATION PROGRAM FOR ELEMENTARY EDUCATION MAJORS

Patricia A. McClurg
University of Wyoming

AN INTEGRATED SEQUENCE FOR ELEMENTARY MAJORS

Sandra Harpole
Mississippi State University

DEVELOPING A COHESIVE PROGRAM--PRESERVICE PROGRAMS FOR TEACHING ELEMENTARY SCHOOL MATHEMATICS AND SCIENCE

Jack Wilkinson
University of Northern Iowa

DEVELOPING A COHESIVE PROGRAM

Gail Shroyer
Kansas State University

THE DEVELOPMENT OF A COHESIVE SCIENCE EDUCATION PROGRAM FOR ELEMENTARY EDUCATION MAJORS

Patricia A. McClurg
The University of Wyoming

Rationale and Objectives

The goal of our program arose from a simple reversal of the state of elementary school science education being reported during the last decade. Examination of objective data and of teacher self reports indicated that graduates of elementary education programs typically dislike science, exhibit low levels of confidence in personal ability to teach science, often lack knowledge or understanding of science content, and allocate very little time to science instruction in their classrooms (National Science Board, 1983; Task Force on Education for Economic Growth, 1983; Feistritzer & Boyer, 1983). Our mission is clear - we want to restructure our program to produce elementary teachers who can and who will effectively teach science to their elementary school students.

If we are to be successful we must produce teachers who:

(1) are confident in their ability to learn and to do science;

(2) are knowledgeable
    who have a solid foundation in science content;
    who have a realistic view of science and technology;
    who are competent in designing and implementing
        effective science instruction;

(3) are excited about teaching science and

(4) exhibit a positive attitude toward science.

Approaches: Cohesion vs. Adhesion

Webster's New World Dictionary (1988) includes the following definitions:

Adhesion: the state of being stuck together . . . the force that holds together the molecules of unlike substances whose surfaces are in contact. (page 16)

Cohesion: tendency to stick together . . . the force by which the molecules of a substance are held together. (page 272)

At the time we developed our proposal the existing science education program for elementary teachers at the University of Wyoming would at best have to be classified as adhesive. Unlike courses were stuck together in a superficial and linear fashion typical of many programs. Prospective elementary teachers were required to take only nine semester hours of science and/or mathematics which were usually elected in a haphazard way. In a subsequent semester, most often several semesters later, students would take a science methods course. This was followed by a student teaching semester under the direction of an arbitrarily assigned teacher who frequently did not teach science or who taught science as another reading class.

The challenge and the basis of our experiment was the complete restructuring of this program to produce a cohesive model. Several lines of educational research guided our deliberations. Researchers examining student understanding of science phenomena were uncovering many widely-held misconceptions or alternative conceptions (Eaton, Anderson & Smith, 1983; Nussbaum & Novick, 1981; Smith & Anderson, 1981; Stepans, Beiswenger & Dyche, 1986) which we could not ignore. Strong support for the effectiveness of "hands on" strategies in teaching elementary school science emerged in meta-analyses (Anderson, 1983; Bredderman, 1983; Shymansky, Kyle & Alport, 1983). Research examining the effect of models of teaching on student achievement identified several instructional strategies with potential to substantially increase student achievement (Joyce & Showers, 1988). Two of these models, cooperative learning and inquiry, seemed integral elements of the successful hands-on science programs. Yet these very strategies are complex and or known to require extensive training and practice (Joyce & Showers, 1988; Johnson, Johnson, Holubec & Roy, 1984; Joyce, Showers, Dalton & Bealon, 1985; Fullan and Pomfret, 1977). An understanding of the theoretical underpinnings of the strategy, observation of expert models, practice with feedback and coaching during transfer to the classroom are essential elements of such training (Joyce and Showers, 1983; Johnson, et al., 1984). The need for such training is reflected in Berliner's (1985) recommendations for much needed "pedagogical laboratories" in preservice education - places where prospective teachers can

> have students to whom one can teach concepts, where expert teachers can provide critiques of the lessons, and where the peers of the novice teacher and the children themselves can join in the analysis of the teaching activities that have just occurred. We must provide our novice teachers with environments in which to experiment with producing cognitive and affective change in children. (Berliner, 1985, p. 6)

It became apparent that we must abandon our adhesive linear model and embrace a cohesive parallel processing model. The very essence of our courses and practicum experiences must be made of the same substance and must reinforce each other. To accomplish this we had to adopt processes which would cause the people involved in the program to work in concert. Three major components - science content, instructional strategies and techniques and work with professionals in the field - were identified as essential to the preparation of preservice teachers. This meant enlisting the cooperation of faculty in four colleges within the University (Arts and Sciences, Agriculture, Education, and Engineering) and a cadre of public school teachers. Teams of individuals representing each of these components worked together on the development, testing, revision, and implementation of each course or experience. Formative and summative evaluation is being collected on two groups. Revisions are made following each pilot group experience and the retested on a larger experimental group.

Details of the development of each of these components are reported in other papers in these proceedings (see Panel 1/Beiswenger, Panel 2/Stepans, and Panel 6/McClurg). Here I would like to focus on the parallel processing aspect of the model illustrated in Table 1.

While each component has a primary focus it reinforces the other two components which are operating simultaneously. A student taking a content course is also enrolled in a parallel seminar with required experiences with mentor teachers in public school settings. Thus, when learning about a science topic the preservice students are also exposed to activities appropriate for elementary children on the same or related topics. They also interview elementary children to determine their ideas about science concepts. Students are introduced to teaching strategies in the seminar, experience the strategy as a learner in the content course, and observe the strategy being implemented in an elementary classroom. During a practicum associated with methods and during student teaching experiences, students must draw on content knowledge to develop units which incorporate targeted teaching strategies. Practicum experiences include feedback via peer coaching and expert coaching which continues when they join a mentor coaching team during student teaching.

Table 1
Parallel Processing Model

	CONTENT	INSTRUCTIONAL STRATEGIES & TECHNIQUES	WORK WITH PROFESSIONALS IN THE FIELD
3 CONTENT COURSES (Interdisciplinary)	Basic Concepts Applications to Society Ways of Knowing Recurring Themes	Model targeted strategies Reconfiguring time Risk taking	Observe science content
3 PARALLEL SEMINARS	Develop interview questions Content appropriate at each level	Model targeted strategies Reflective exposure to curriculum materials	Interview elem. students Model targeted strategies Debriefing sessions
METHODS	Identify and summarize concepts	Questioning Curriculum materials Assessment & evaluation Integrated Units	Peer coaching Expert coaching
STUDENT TEACHING	Identify and summarize concepts	Students design and implement lessons	Member of a coaching team

Outcomes

We invited one of the students from the pilot group who was finishing her student teaching semester to speak to our experimental methods students. After a brief summary of her experiences she asked the class if they wanted to ask her any questions. After numerous questions about class management, housing acquisition, and mentor teachers, one of the methods students asked "I feel confident about teaching science, but I am worried about what to do in the other subjects like Language Arts - how did you know what to teach?"

The response was equally astonishing. "I know what you mean - I started out feeling the same way. Don't worry you will get to observe the mentor teacher before you have to teach. They have textbooks and the mentor teacher will help you with it."

Such a question and response seemed unbelievable to us. Years of prior experiences had been quite the opposite with our methods students expressing apprehension about teaching science topics. It meant that we were beginning to see tangible results of our program. The pilot group has finished the content/seminar methods course sequence and are currently student teaching. The experimental group is finishing the methods course and making plans to student teach next year. Formative data collected to date on each of these components is positive. Pre-post test scores show statistically significant gains in each of the content areas. Interviews and anonymous written responses indicate that the success of one component is interrelated to the success of other components. For example, one student indicated that he was having trouble interpreting maps in his content class until he completed an activity in the seminar. Another student questioned the value of seminar until she observed a mentor teacher in action and then realized she needed to develop a teaching repertoire. Another student related that her interest in the content class increased exponentially after interviewing a few elementary students about their understanding of related science concepts. The final test of these experiences will have to wait two to three more years when we follow these students into their inservice experience to see to what degree they are (1) teaching science, (2) using effective teaching strategies and (3) acting as change agents in their educational communities.

Figure 1 depicts the components of content, instructional strategies, and work with professionals as puzzle pieces which form the core of a larger puzzle. To maintain the program these core pieces must fit into the larger context of the

University. The College of Education recently adopted a new extended teacher preparation program; the faculty voted to require the newly developed sequence of courses, seminars and practicum experiences in science education for all elementary education majors. Recent changes in University Studies increased the science requirements to a minimum of two lab sciences for all students at the University of Wyoming. This had positive consequences for our program since we had increased science requirements to three lab sciences for elementary education majors. Two of the three content courses have obtained approval for meeting University studies requirements. The third course is in line to submit for approval this year.

The initial successes of the model has necessitated expansion of our program. The implications of the new science education requirements for all elementary education majors reach at least two components of the state community - the third layer in our puzzle. During our project we worked with twenty local and twenty out-of-state mentor teachers. In our state several hundred more teachers need to be included if the cohesive, parallel approach is to be maintained for all students. Approximately fifty percent of education majors at UW transfer into the program after attending one of the state's seven junior colleges. Articulation measures need to be put into place to insure the development and availability of similar experiences in these settings.

The smoothly fitting puzzle pieces in Figure 1 may be deceiving. Successes to date have been the result of collaborative processes among true partners which translates into many hours of dialogue, and continuing effort to maintain open lines of communication. Although the puzzle pieces at the University level seem to be falling in place, changing administrators (including two new Deans and four new Department Heads in a three year period) must be convinced of the value of the project if support is to be maintained for the program.

Developing and Maintaining a Cohesive Program

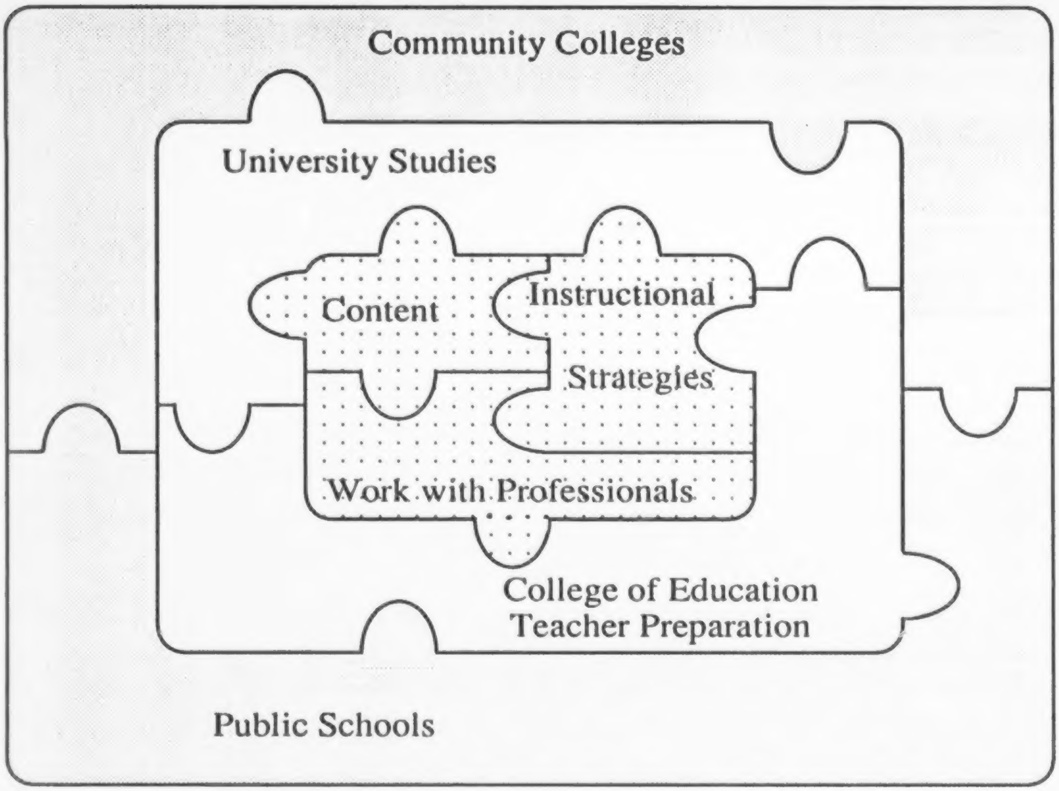

Figure 1

Developing and maintaining a cohesive program.

Recommendations

We are excited by the preliminary results of our experimental parallel processing model and encourage others to experiment with it. Our experiences lead us to believe that what we have to offer other institutions is a process rather than a finished product. We have completed extensive syllabi for each of the courses and workshops that we developed. However, handing these to another institution as a curriculum would not result in a cohesive program. The cohesiveness of the program is a result of the dialogue, the disagreements, and the resolution of differences among the personnel designing the experiences in all three components of the program.

The process must be flexible and must provide avenues for induction of new personnel. During the short time our project has been operational one faculty member has become an administrator, one has moved and one has chosen not to continue to participate. We are currently experimenting with having a new team member spend a semester assisting in a class before becoming the primary instructor. Our hope is that this interaction will spur continued dialogue and revisions, expand the number of available personnel and help maintain faculty enthusiasm.

The cohesiveness of our program assumes equal partnership among members of all three components represented in the model. Thus, processes which insure ongoing communication and updating among all the components are imperative to the vitality of the program.

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AN INTEGRATED SEQUENCE FOR ELEMENTARY MAJORS

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Mississippi State University

Mississippi State University, like many other universities, required six hours of science for a major in elementary education, three in biological science and three in physical science. The courses of choice were botany and geology. Concern over this limited preparation of elementary education majors in science led to the development of this project with the ultimate goal of improving the quality of science instruction in the elementary schools. This five-year project, in its second year, provides preservice teachers with solid content while preparing them to teach hands-on science in the elementary classroom.

A project conducted by the College of Arts and Sciences for an audience in the College of Education requires involvement and cooperation of the College of Education to be successful. Before the proposal was submitted, an overview of this project was presented to COE faculty with a request that they raise the requirements for elementary education majors from six hours of science to twelve hours of science, specifically the twelve hours developed by this project. That commitment, to begin with freshmen elementary education majors entering Mississippi State University in the Fall, 1991 was obtained prior to submission of the proposal.

The majority of teachers at all levels tend to teach as they have been taught. Since the integrated sequence of science courses developed by this project is taught by Arts and Sciences faculty, model teaching by academic faculty is a critical element in placing teachers in the elementary classroom who are prepared in content and practice good teaching strategies. A series of weekend workshops were conducted by both nationally known and Mississippi consultants with expertise in areas relating to science teaching. All Mississippi State University faculty as well as science and education faculty from the other seven Mississippi universities and fifteen community colleges were invited to attend Friday afternoon sessions. Faculty also attended biweekly sessions conducted by the Faculty Development Center. The goals of these programs were to acquaint academic faculty with current pedagogy and prepare them to serve as model teachers for preservice teachers to emulate as they move into the elementary classroom. Workshop topics included Current Research in Science

Education, computers in Science Education, Process Skills, Critical Thinking, Writing Across the Curriculum, and Science Education in Mississippi.

Each course developed through this project carries a total of four credit hours, three hours per week spent in lecture and three hours per week in laboratory. The content includes physics, astronomy, chemistry, geology, meteorology, and biology. Faculty from these areas who team teach the courses were involved in the development of the course materials and accompanying laboratories. Preparation began during the academic year as an integral part of the faculty development workshops, but the major development was done during the summer of 1991. Four outstanding Mississippi elementary teachers served as consultants during the developmental phase to put university faculty in touch with the real-life classroom situation. They assessed content material to determine the need for particular content background and laboratory exercises for adaptability to the elementary classroom.

The second year has focused on implementation of all three of the new/revised courses for the first time during the fall, 1991, semester. The enrollment consisted not only of elementary education majors but other nonscience majors seeking to meet the science requirement of the core curriculum. Four graduate students, two from the College of Education and two from Arts and Sciences, teach the laboratories and prepare teaching manuals for each lab, and prepare a general guide for graduate assistants teaching these types of labs.

Continuous revisions have been taking place during the course of the year. Weekly meetings are held with all graduate assistants and close contact is maintained among the teaching professors to assess the effectiveness of laboratory activities and classroom presentation. The second round of teaching during the spring of 1992 will reflect these changes.

Following the completion of the three-course sequence, preservice elementary teachers will apply content knowledge and laboratory skills to the elementary classroom situation through the elementary science methods class. Lesson plans should demonstrate an increased content knowledge and will translate laboratory activities into activities that are appropriate and meaningful for children.

The ultimate test of the effectiveness of this program will be what happens in the classrooms of teachers trained in this program. While preparing to teach they must be placed in classroom situations that make use of the content and teaching strategies they have observed in our courses. To insure positive experiences during both observation periods and student teaching experiences, preservice teachers will be placed with mentor teachers.

A three-week workshop will be held during the summer of 1992 for teachers selected by area school districts to prepare them to serve as mentors. The workshop content will be physics, an area in which the elementary teacher consultants felt a weakness, and will utilize effective teaching strategies. Our students will be placed with these teachers during their practicum, in which they observe in local schools, and during their student teaching experience. They will work with teachers who will teach science using hands-on methods and who display a positive attitude toward science.

The final phase of the project will be to evaluate our students during their first year of teaching. Contact with students will provide encouragement and support as well as an assessment of the effectiveness of their training. There will be on-site visits with students as well as a conference on campus where students will be able to interact and discuss their experiences.

Recommendations and Considerations

A project involving two colleges and faculty from various departments requires both planning cooperation prior to submitting a proposal and cooperation and communication during the implementation of the project. The courses and laboratories developed are integrated courses with topics taught by faculty with expertise in the area. Topics are covered as they fit into the sequence, not to match a schedule convenient to the faculty. Coordination of teaching schedules of the various departments is a huge task. The chairs of the departments involved have been most cooperative in assigning a professor to a time slot in which he or she will not teach a full semester of class sessions. The question of FTE has been difficult to resolve as our university is closely scrutinized by the Board of Institutions of Higher Learning. Locations of classrooms and laboratory facilities had to be determined. Discussions of all of these issues must take place during the planning stages of the project. They cannot be decided after the grant is received.

The administration of the project is very time consuming. With the number of faculty involved and four teaching assistants, there is a large amount of paperwork. Regular meetings of faculty and graduate students are necessary both to make revisions as needed, to coordinate teaching material, and to assess the effectiveness of materials and teaching methods.

An important consideration is initial long-term commitment by the university and the colleges and departments involved. Since the project was initially planned, the people involved have included a provost, a dean, an associate dean, two department heads, and the co-principal investigator. Additionally, our state has faced severe budget cuts and reduced funding at the university level. The initial commitment made by our university to this project has made its success possible in spite of these problems.

DEVELOPING A COHESIVE PROGRAM–PRESERVICE PROGRAMS FOR TEACHING ELEMENTARY SCHOOL MATHEMATICS AND SCIENCE

Jack Wilkinson
University of Northern Iowa

Rationale and Objectives

The reason for the need to integrate classroom work, the student-teaching experience, and the induction year is to maximize the effectiveness of the preservice program for elementary education teachers. In too many cases the effect of preservice on campus work is quickly eroded by placing student teachers in settings which are not compatible with the methods instruction in campus classes. The transition into the first year of teaching can also erode many of the positive impacts of the preservice program.

Project Goals

1. To prepare outstanding elementary teachers in science and mathematics with a strong background in content and pedagogy in the mathematics and science disciplines and in thinking.

Project Objectives

1. To foster understanding of the nature of mathematics and science in preservice elementary (math and science) teachers.
2. To learn to communicate mathematics and science.
3. To value mathematics and science.
4. To recognize the complementary nature of mathematics and science concepts.
5. To help teachers recognize concepts common to both mathematics and science and to aid them in integrating these concepts.
6. To integrate the appropriate use of calculators and computers into mathematics and science courses.
7. To use audiovisual media in mathematics and science courses, preservice methods, field experiences, and inservice training of supervisory and support network staff.
8. To provide sufficient level and breadth of content in mathematics and science for competence in teaching at the elementary school level.

9. To engage preservice teachers in mathematics and science courses that are concept and process oriented and experiential and activity-based.
10. To teach preservice teachers as we want them to teach by modeling the learning cycle teaching approach.
11. To employ problem solving and critical thinking in the learning cycle teaching approach.
12. To cause preservice teachers to reflect on the way they have been taught in project courses.
13. To put an emphasis on integrating theory into practice in the respective mathematics and science methods courses.
14. To provide in-class observations and discussion in all mathematics and science courses on the teaching approach and appropriate supporting teaching strategies being employed in the courses.
15. To provide extended field experiences for the preservice teachers to teach by the learning cycle approach.
16. To provide supervisors of field experience and student teaching with experience with the learning cycle teaching approach so as to support the content and pedagogy learned by the preservice teacher.
17. To create a support network of project staff, university educators, school administration and area educators to aid in transition from preservice to inservice teaching.
18. To incorporate the Curriculum and Teaching Standards from the National Council of Teachers of Mathematics into the mathematics program.
19. To provide the support network staff with the goals and objectives of the project and direct experience with the teaching model so they can promote the continuance of quality mathematics and science teaching at the elementary school level.
20. To provide the preservice teachers with early experience in professional developmental activities and encourage project graduates to continue their professional development towards leadership positions in elementary school science and mathematics.
21. To provide professional development vehicles on the UNI campus: yearly content updates in science and mathematics, summer teaching methods workshops and inservices, annual Fall Mathematics Conference.

Approaches

A preservice program for elementary mathematics and science teaching:

a) must integrate content and pedagogy in all courses;
b) must use technology (both calculator and computer) in an appropriate way;
c) must link with the student teaching part of the preservice program;
d) must attempt to link the preservice program into a mentor/induction program for first and second year teachers.

Content of the program. The elementary education program at UNI has built a preservice model which encompasses all of the above features. Specific program information is outlined below.

1. The elementary education major at UNI is required to take a minor in one of the curricular fields commonly taught in the elementary school. Typically these minors are 24 semester hours of content and pedagogy. It is important that text materials and instructional delivery reflect the unified nature of the mathematics and science content in concert with the best thinking regarding the teaching of mathematics and/or science.
2. It is advisable to use mathematicians and scientists need to be used as consultants in the content dimension. It is also advisable to have classroom teachers review these curricula materials as they are being developed.
3. Preservice teachers need to have a clear view of when to use calculator technology, when the computer technology is the technology of choice, when pencil and paper technology is best and when to rely on mental computation skills. The technology (both calculator and computer) should be integrated in a meaningful way into all courses.

The first phase of any program consists of having a series of courses which develop the big "threads" or strands which are common to all courses. In this project the strands are:

a) infusing problem solving and the learning cycle into all courses.
b) integrating appropriate technology into all courses.
c) integrating content and pedagogy - teaching sound mathematical and scientific ideas in a meaningful, developmentally appropriate way.
d) integrating labs and activity-based learning into every course.

e) integrating mathematics and science in a consistent and meaningful way.

The 24 hour program in mathematics and the companion 24 hour science program have been developed to maximize the impact of a-e above. It is our goal to have a *program* rather than a series of courses.

Student teaching. The *second phase* of a comprehensive program for preservice teachers encompasses work with cooperating teachers who will supervise the student teaching. These cooperating teachers must have the opportunity to help shape the content and methods of the "on campus" courses in the preservice program. Also they must become knowledgeable and experienced with the activities, strategies, and processes which make up the content of the preservice teacher program. This part of the program is carried out through summer workshops of 5-10 days. In the UNI program a two-week workshop was conducted in the first summer and the following summer we conducted a one-week workshop for each set of participants. In summers 3, 4, etc. one could schedule two or three day maintenance workshops. This seems to be easier to implement than to have teachers come onto campus during the academic year. Academic year contact is important and is most efficient when groups of teachers return to the campus for a one-day workshop. These have been difficult to carry out because it is very hard to get teachers released from classes.

Project faculty also conduct on-site visits to schools which accept our student teachers. Once each semester, student teachers and their cooperating teachers return to campus, or to a mutually accessible site, for late afternoon, working dinner and evening meetings. These usually last from 4:00 to 5:30 or 5:30 to 8:30 PM and provide an opportunity for discussion, question asking, question answering and a chance to critique the program and specific courses.

The *third phase* of a comprehensive program is to supply support and leadership in the induction years (1 and 2) for beginning teachers. Due to local school autonomy, the institution needs to develop two or three model programs which have the potential to meet the needs of first year teachers. Once a series of model programs is developed the institution can "broker" programs which meet the needs of first year teachers and the schools in which they teach. One model would establish mentor/mentee relationships for every first year teacher. This building level relationship could also be enhanced by the addition of the school principal to form a three-person group. It is likely that other professional agencies will actually carry out the on-site, day-to-day support efforts for the first year teacher.

A second model is being developed which will provide "long distance" services to first year teachers. Examples of long distance services include: newsletters; encouragement to attend professional meetings with the institution hosting a meeting of graduates within the schedule of the professional meeting; electronic mail; telephone support; and hosting conferences which have sectional meetings devoted to first and second year teachers.

The follow-up of graduates should become a regular part of a Curriculum and Instruction division effort in teacher education. The UNI project described in this paper simply provides a start-up model for this long-range program. The follow-up programs which we are developing are of two types. One is quite informal and consists of mailings and occasional meetings. A second level program calls for our staff to visit first and second year teachers in their respective buildings, with building support provided by mentor teachers and principals.

A cohesive program from a university prospective must also include the programs at the university which work with those who teach the professional core courses in the preservice teacher education program. In the case of UNI these courses are offered in the College of Education while the content and methods courses in science and mathematics are offered in the College of Natural Sciences. Communication and common efforts between these two facets of the program is needed.

Instructors in curriculum and instruction, educational foundations, special education, early childhood education, media/technology, and the like all need to be included in the "loop" in order to have a comprehensive program. This linkage to other departments and other colleges can be carried out by having joint meetings (at least one per semester) and by adding persons from those divisions to steering committees and advisory boards. Much of what we do under the umbrella of the new NCTM Curriculum Standards and the Teaching Standards can easily be generalized to several areas in the preservice program. For example, the first four curriculum standards: teaching connections, enhancing communication, teaching children to reason and the teaching of problem solving can be generalized to many curriculum and professional education courses. Bridges to other departments must be built and maintained.

Comprehensive programs must also include the private sector. State mathematics coalitions exist in approximately 45 of the 50 states. Preservice teacher education programs must have representation on coalitions which incorporated the talents of the private and governmental sector in unison with the educational community.

Outcomes/Effectiveness

The evaluation of both cognitive and attitude measures give a positive picture of the overall effect of the classroom component. The assessment of student beliefs requires a longitudinal effort and results on beliefs are just starting to be assessed. One very promising aspect of the evaluation has been the numbers of students selecting the science and mathematics minors. In each area (science and mathematics) we have over twice as many students as we had planned for in our initial projection.

The assessment of the second phase of the project involves the work with cooperating teachers and their student teachers. This phase of the program has had exceptionally positive written reviews and has had excellent testimony from the cooperating teachers.

Recommendations

The generalizabilty of this three phase program rests on the ability of the institution to work with cooperating teachers. The content/methods component is a common component of most preservice programs. The linking of the on campus institution to the student teaching/cooperating teacher segment is unique and requires some external support. Having teachers come to the university campus and receive instruction on the nature of the preservice program provides a solid base for enhancing the student teaching experience. An additional feature of this on campus summer experience is that it gives the university staff an opportunity to learn about the programs which are in place in the respective school districts. This phase has some budget needs which would require external funds.

The third component, the induction year phase can take many forms and can be transferred to institutions without external support. Newsletters, meetings at professional conferences, and telephonic or computer networking could serve as a minimal level program. On site mentors or mentor committees could help first year teachers at the building level. One mentor teacher and a principal could form a two-person induction committee which would help the first year teacher. Local teachers who are active in the state mathematics or science teachers could also serve on the mentor committee. The building level committee could be formal or informal and as extensive as resources permit.

In summary, only Phase II, the cooperating teacher/student teaching would require external funds. The other components can be implemented without the need for external funds.

DEVELOPING A COHESIVE PROGRAM

Gail Shroyer
Kansas State University

Rationale

We live in an age that demands children to deal with complex scientifically, mathematically, and technologically related problems. The ability of elementary students to succeed in adulthood is critically linked to developing basic skills in mathematics and technology, and becoming scientifically literate. Reports from various concerned groups continue to suggest that American education is not preparing students for success in the 21st century (AAAS, 1989; IAEEA, 1987 & 1988; Mullis & Jenkins, 1988; NCTM, 1980 & 1989; NRC, 1989). According to many of the reports, undergraduate teacher preparation programs are the key to reform in science, mathematics, and technology education at the elementary and secondary levels (AAAS, 1970; NCTM, 1991; NSTA, 1988; Holmes, 1989).

In the spring of 1989 Kansas State University conducted a needs assessment of its elementary preservice program in mathematics, science, and technology education. As part of this assessment, a survey was completed by student teachers and their cooperating and supervising teachers. The results indicate that in every instance mathematics, science, and technology teaching were ranked lowest by student teachers, cooperating teachers, and supervising teachers in terms of student confidence and experiences during student teaching. Project participants viewed the results of the student teacher survey as reflective of inadequacies in the teacher education program. Prior to the NSF project, Kansas State University provided very little science and mathematics for preservice elementary teachers (12 semester hours of science and 3 semester hours of mathematics); the science and mathematics courses were not integrated with methodology courses on teaching science and mathematics; and students were not provided with sufficient opportunity to develop and enhance skills and systematically observe and participate in real school settings. The Kansas State University elementary program did not meet recommended teacher preparation standards (AAAS, 1970 & 1989; NCTM, 1980, 1989 & 1991; NCISE, 1989; NRC, 1988; NSTA, 1983 & 1988). Like most institutions (Stedman & Dowling, 1982), Kansas State University had not specifically designed its science and mathematics courses to meet the needs of elementary teachers. Kansas State University did not offer interdisciplinary science/mathematics courses and had not established collaborative relationships between the groups of individuals jointly responsible for preservice elementary teacher preparation.

Because practicing elementary teachers often model their science and mathematics teaching behaviors after university faculty who teach science and mathematics courses (Andersen, 1979), we determined that the Kansas State University NSF project faculty needed to design preservice courses to meet the needs of future teachers and to teach these classes as faculty expect preservice students to later teach their elementary students. All participants agreed that reform was needed in the Kansas State University teacher training program to enhance the preparation of elementary teachers to provide the mathematical, scientific, and technological education necessary for all students to fully live, work and democratically participate in today's complex technological world.

To develop solutions for the problems of preparing the future generation of elementary teachers, a project team composed of faculty from Kansas State University's College of Education and College of Arts and Sciences, in partnership with the Manhattan-Ogden public school system, have devoted the past year to developing a new model for the preparation of future teachers. The focus of this five-year innovative project is to develop, field test, revise, institutionalize and disseminate a research-based preservice model program to prepare elementary teachers for enhanced science, mathematics and technology teaching. Four key premises underlie program development. Preliminary teacher preparation must include: (a) an articulated, unified program collaboratively developed by content specialists, education specialists and school practitioners; (b) a broad and solid integrated foundation in science, mathematics and technology content; (c) rigorous and effective methods of teaching science, mathematics, and technology based on innovative practice and current research; and (d) extensive field experiences in diversified school settings with mathematics, science and technology teaching. (See Appendix A for a complete description of project goals and objectives.)

Approach

According to many major reports, undergraduate teacher programs are the key to reform in science, mathematics, and technology education (AAAS, 1989; NRC., 1988; NSTA 1988). These reports advocate reconceptualized research-based teacher preparation programs that: (a) deepen and extend students' understanding of mathematics, science and technology; (b) are designed cooperatively by scientists, mathematicians, educators, and school practitioners; and (c) teach the concepts and structure of science, mathematics, and technology in a fashion that is congruent with the ideals of the scientific enterprise and the true spirit of science.

During the fall 1990 semester Kansas State University began a major university wide project supported by a grant from the National Science Foundation to reform elementary mathematics, science and technology preparation based on the above recommendations. A major focus of the project was the creation of a partnership between the College of Arts and Sciences, the College of Education, and the Manhattan-Ogden Public Schools, according to guidelines established by the Holmes Group (1989). The partnership model is illustrated in Figure 1, "Integration of Knowledge in Science, Mathematics Methods, and Field Experiences in Elementary Teacher Preparation."

Project participants are committed to the vision that teacher preparation— directly as well as indirectly— must be a joint responsibility involving all groups of professionals involved with teacher preparation. Three professional development schools have been created in the public school system as an outcome of this collaborative effort. The professional development schools and the partnerships between the Colleges of Education and Arts and Sciences, and the public schools will serve as a model for Kansas State University's total teacher preparation program at the conclusion of the project.

Project Participants

The project began in the fall of 1990 with the selection of project participants. Eighty-six people have been involved in the project during the first one and one-half years. Project participants include twenty-seven undergraduate students, twenty-eight teachers, six public school administrators, and twenty-five Kansas State University faculty.

Project co-directors established criteria for the selection of the professional development schools and the administrators and teachers to be involved with the project. Based on jointly developed criteria, three professional development schools were selected. These elementary schools (Amanda Arnold, Lee, and Woodrow Wilson) will function as sites for systematic and long-term preservice field experiences. Three clinical instructors were chosen to serve as half-time district teachers and half-time University project faculty. The clinical instructors will co-teach courses and coordinate all field experiences. Twenty-five full-time teachers were selected as master teachers to supervise all field experiences. All twenty-eight teachers are co-developers of new courses and field experiences.

University participants from the College of Education and the Departments of Biology, Biochemistry, Chemistry, Geology, Mathematics, and Physics were also finalized in Fall 1990. The university faculty consists of six scientists, two mathematicians, five science educators, two mathematics educators, two technology educators, one generalist elementary educator, four graduate assistants, two support personnel, and one secretary.

Science and Mathematics Courses

We believe that many university educators need to restructure their thinking about instruction. The constructivist model of how students learn (Champagne and Hornig, 1987) provides a model of how teachers learn as well (NCISE, 1989). Constructivism asserts that learners construct their own unique interpretation of knowledge of the world by integrating new information with prior procedural and declarative knowledge. We intend to utilize, in all science and mathematics courses, the constructivist perspective on learning and instructional models (such as the learning cycle) that are consistent with a constructivist perspective. In this manner we are providing instruction in science and mathematics that enhances learning while simultaneously providing a model of appropriate science and mathematics instruction for future teachers.

Nine science and mathematics courses, 32 semester hours total, are in various stages of development. It is our intent to provide a broad and solid foundation in science and mathematics appropriate for enhanced elementary teaching. Science requirements include 16 semester hours of science laboratory courses divided into 4 semester hours each of biology, chemistry, physics, and earth/space science. Three new mathematics courses, 10 semester hours total, are being developed and two new interdisciplinary science-mathematics-technology courses, 6 hours total, are being created. Formal courses and field experiences will be developed, field tested, and institutionalized in three cycles. Each year for three years, new classes will be developed and field tested. They will be evaluated and revised the summer following field testing. The revised courses will be institutionalized the following year. Following this procedure, the first cycle of classes was field tested during the 1991-1992 year. They were evaluated and revised during the summer of 1992, and institutionalized the next year, 1992-1993. In this manner, field testing, evaluation, and institutionalization will be a continuous process. (See Figure 2: Program Framework, for the schedule of course development.). The interdisciplinary course, "Introduction to Scientific and Mathematical Thinking", was created to precede advanced content course work. This problem-solving course, taught during Fall 1991, introduced students to laboratory and process skills and foundational science, mathematics, and technology concepts and principles. The second interdisciplinary science/mathematics course, to be taught at the end of the program, will be created to unify science and mathematics themes through a focus on technology and societal issues.

Methodology Courses

Educational methodology requirements will include courses in science education (biology, physical science [chemistry and physics], and earth/space science), mathematics education, and interdisciplinary science/mathematics/technology education. Students will take the appropriate methods course at the same time they are enrolled in the science or mathematics course. (See Figure 2: Program Framework). In addition, students will complete existing elementary education certification requirements. Courses are being created based on constructivist premises and will incorporate current research-based developments in inquiry-based instructional models, critical thinking, cooperative learning, peer coaching, effective instruction, educational technology, and curriculum development and evaluation.

A wide variety of field trips, both on and off campus, have been also identified to focus science and mathematics education on technology and societal issues. Visits to research centers, power plants, the water department, factories and local field research sites such as the Konza Prairie provide students with firsthand experiences in how to apply science and mathematics to real situations.

Instructional methodology courses will teach about, as well as utilize advanced technologies, such as microcomputers and videodiscs in instruction. The elementary preservice teachers will become computer literate and will learn to infuse computers and other new technologies into the elementary curriculum.

Figure 2: Program Framework

Horizontal Integration between content, methodology, and field experiences

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Vertical Integration between science and mathematics domains

	content courses	methods courses and field experiences		
	1st cycle (field tested year 2, institutionalized year 3)			
fall	introduction to scientific and mathematical thinking (3 hr.)	process skills and problem solving methods	<—> (1 hr.)	introduction to field experiences
spring	mathematics (4 hr.)	mathematics methods	<—> (1 hr.)	mathematics field experiences
	biology (4 hr.)	biology methods	<—> (1 hr.)	biology field experiences
	2nd cycle (field tested year 3, institutionalized year 4)			
fall	physics (4 hr.)	physical science methods	<—> (1 hr.)	physical science field experiences
spring	mathematics (3 hr.)	mathematics methods	<—> (1 hr.)	mathematics field experiences
	chemistry (4 hr.)	physical science methods	<—> (1 hr.)	physical science field experiences
	3rd cycle (field tested year 4, institutionalized year 5)			
fall	earth/space science (4 hr.)	earth/space science methods	<—> (1 hr.)	earth/space science field experience
	mathematics (3 hr.)	mathematics methods	<—> (1 hr.)	mathematics field experience
spring	interdisciplinary science/mathematics/ technology (3 hr.)	interdisciplinary methods (1 hr.)		student teaching (8 hr.)

Totals:				
	mathematics	10 hr.	mathematics methods	3 hr.
	science	16 hr.	science methods	4 hr.
	interdisciplinary math/ science/technology	6 hr.	interdisciplinary methods	2 hr.
	Total Content	**32 hr.**	**Total Methods**	**9 hr.**

Educational methods courses are also being developed to stress the importance of interdisciplinary teaching at the elementary level. Instructors in language arts, reading, social studies, and instructional technology methods courses are developing unit modules focused on strategies for infusing mathematics, science, and technology into their content areas. These modules will be based on current issues, such as environmental education, which can be used to combine science, mathematics, reading, writing, and social studies.

Field Experiences

Extensive field experiences are a major component of the teacher preparation model. Field experiences began Fall 1991, during the students' sophomore year, as observations and individual tutoring. They were expanded to small group tutoring, then small group instruction, and finally large group instruction. These first year field experiences have involved the preservice students in mathematics, science and technology after school clubs, conducted at the professional development schools. The students are learning to write and conduct daily lesson plans during the first year. These skills will be expanded to unit planning and resource development and finally course planning and text selection. The aim is to provide the students with extensive practical experiences which will result in their ability to plan and carry out a comprehensive student teaching experience during their senior year. Kansas State University faculty and USD 383 teachers have jointly created guidelines for these field experiences.

Professional development objectives have been created to guide field experience expectations. Evaluation criteria are also being developed to assist in the systematic evaluation and monitoring of these professional objectives. Evaluation criteria will be based on a wide variety of assessment techniques, including portfolios, case studies, and reflective journaling. Student evaluation may, therefore, include observations from supervisors, examples of lesson planning and curriculum development, evaluation surveys from students, cooperating teachers, and supervising teachers, and checklists of teaching competencies representing both generic and specific teaching skills in science and mathematics. Students have been provided with professional development objectives and they will be provided with opportunities to practice and perfect the effective instructional techniques expected of them. Intensive supervision of field experiences and continuous student feedback will be provided by university specialists, the clinical instructors, and the public school master teachers.

The project's concept of field experiences will extend into the students' full-time teaching experience. The 26 cadre students who graduate in year 4 will be monitored during their first year of teaching, project year 5. This system will be used in the project to provide support and to monitor the success of the program graduates. In addition, graduates who are teaching in the fifth year of the project will become an important component of the project evaluation to determine the effectiveness of the model program and areas of needed improvement.

Outcomes/Effectiveness

Overall, we are quite pleased and excited about our progress over the past one and one-half years. This period of time has been extremely busy and productive for the NSF elementary teacher project participants. Reflecting on our goals for year one, it is obvious that we attempted a vast number of complex activities. And yet all of these goals were accomplished.

An evaluation design was created as part of our first year activities. Since this is a fairly new project, the majority of our first year information is baseline data. During 1990-1991, numerous questionnaires were given to teachers and parents from the professional development schools. Observational data and interviews were also collected about the professional development schools, clinical instructors, master teachers, administrators, Kansas State University faculty and the first cadre of undergraduate students. This information will be used to document project effectiveness at the end of year five.

During the 1991-1992 year, we continued data collection with a second round of interviews with clinical instructors, administrators, and parents from the professional development schools. We have administered numerous instruments to undergraduates before and after our first courses to assess changes in attitudes, cognitive growth and understanding of process skills and the nature of mathematics and science. We will also conduct a second round of interviews with faculty and undergraduates as they complete the field testing of the new courses. We are still in the process of analyzing year two data. We are focusing on perceptions, attitudes and beliefs toward mathematics and science, changes in science and mathematics instruction in the professional development schools and in the Kansas State University college courses, equity issues in mathematics and science, and an analysis of the process of change within organizations.

An overall assessment of project outcomes and effectiveness is based on anecdotal records and evidence from project activities. The greatest impact this project has had on all participants is the area of collaboration and enhanced communication. We have school teachers, administrators, university educators, mathematicians, and scientists discussing ideal teacher preparation, reform in the content and pedagogical knowledge-base for teachers, constructivism, equity issues, reflective teaching, and alternative assessment. Teachers have become familiar with the University and faculty have become familiar with the local schools.

Faculty from Kansas State University and Manhattan-Ogden Public Schools have gained insight into one another's roles as well as trials and tribulations. Scientists, mathematicians, and educators have contributed invaluable ideas and experiences that no single group could have realized alone. We have shared our most idealized goals as well as our greatest limitations with each other and have together struggled with solutions and plans for the future.

Project participants have discussed topics such as reflective teaching, and the use of portfolios and journals from a kindergarten through a college perspective. This has resulted in useful plans for utilizing the conceptualized strategies for the enhanced preparation of future teachers as well as the enhancement of our own teaching kindergarten through college levels.

The project has resulted in numerous collaborative projects between Kansas State University and USD 383. Several action-research projects have been jointly identified between the elementary teachers and the education faculty in the areas of gender/equity and alternative assessment. Several collaborative enrichment projects are also being conducted. Our mathematicians, mathematics educators, clinical instructors, and several of the master teachers have cooperatively established an "Equations" mathematics project for fourth through sixth graders. Our technology educator, language arts educator, and a clinical instructor have collaborated on a hypermedia project and an environmental video project with sixth graders. Eight master teachers and a science educator are involved with several additional district teachers and a project graduate student in an NSF funded BSCS project, **Enlist Micros**. The teachers in this project will provide leadership in their schools to encourage the use of technology in elementary science and mathematics education.

Another major benefit to all participants has been the increased exposure to new ideas and innovative strategies. More district teachers are teaching science than ever before. The size of the district summer mathematics, science, technology magnet school and weekly after school clubs have increased dramatically. Numerous faculty and teachers have attended mathematics and science conferences and workshops. New science and mathematics curriculum and manipulatives are being field-tested across the district. All participants have been exposed to a variety of new technologies and these are being integrated into the elementary schools as well as the University courses. Access to new knowledge and resources has encouraged invaluable improvements in all our courses and this enrichment should increase with time.

Our biggest challenge for this year has been related to our large numbers. We have struggled with techniques to bring the entire group together and yet still remain productive. At this point we have decided to conduct large group events as informational sessions and social gatherings. We have designated our smaller planning teams as our productive units. Consistency in attendance at planning teams is still a problem. It is difficult to get all administrators, teachers and university faculty assigned to each team together at one time. This has slowed our planning process because we spend considerable time at each meeting updating people who missed the previous meeting. We have addressed this problem by distributing formal minutes of each meeting to all team members.

Another difficulty has been communication and coordination among planning teams. We have conducted several meetings of the co-directors who represent all planning teams in an effort to enlarge the sphere of communication. We have distributed team notes and agendas to each school and central office administrators to enhance communication. We now realize that this problem will always be with us because of the size of the project team. The most natural solution is to accept the progress we are making and to realize that this project is not going to move as quickly as we had once anticipated. We are expecting major philosophical and operational changes in all participants and it will take time for all of us to struggle to make sense out of what this means to us individually and collectively. We have all reached an important understanding that the preparation of elementary teachers is a complex and difficult process that demands a collective responsibility. We have made tremendous strides this year but a great deal remains to be done.

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APPENDIX A: Project Goals and Objectives

YEAR 1 - Project Activities

Goal I: KSU will develop a collaborative planning model involving university content specialists, university education specialists, and public school practitioners in the planning and evaluation of preservice courses and field experiences.

Activities

A. A project team will be identified which includes content specialists (scientists and mathematicians), education specialists (science, mathematics, and technology educators and specialists in elementary curriculum and instruction), and school system practitioners (teachers and administrators).

B. A consultant panel will be established consisting of representatives from teacher preparation institutes, the public school system, the community, and the private sector to provide advice and training to participants and to assist with course development and evaluation.

C Planning seminars will be implemented during which the project team will cooperatively develop preservice courses and clinical field experiences.

D. Criteria will be developed for creation of 3 professional development schools.

E. Professional development schools will be created through partnerships with the Manhattan-Ogden public schools to function as sites for systematic and long-term clinical field experiences.

F. Criteria will be developed to guide the selection of exemplary practicing teachers and university specialists as cooperating teachers, clinical instructors and university supervisors for field experiences.

G. Exemplary practicing teachers will be identified to function as master cooperating teachers (25) and clinical instructors (3) for clinical field experiences.

H. Exemplary university content and methodology specialists will be identified to function as supervising instructors for clinical field experiences.

I. Summer institutes will be created for participating practitioners to prepare them for their role as master cooperating teachers.

Goal II: KSU will create a model research-based preservice training program to prepare elementary teachers for science and mathematics teaching.

Activities

A. A required set of science and mathematics courses will be developed for preservice elementary teachers.
    1. A 3-semester hour introduction to scientific and mathematical thinking course will be created that provides students with a background in science and mathematics process and problem solving skills and basic content needed for further science and mathematics course work.

   2. Seven courses will be planned to include 16 semester hours in biology, physics, chemistry, earth/space science, and 10 semester hours in mathematics to provide a strong, broad-based concentration in science, technology, and mathematics.
   3. A 3-semester hour interdisciplinary science/mathematics course will be developed which unifies science and mathematics topics through a focus on technology and societal issues.

B. A required set of educational methods courses will be developed for preservice elementary teachers. These courses will:
   1. Correspond with biological, physical, earth/space science, interdisciplinary science/mathematics, and mathematics content courses.
   2. Focus on innovative effective instructional techniques.
   3. Focus on technology and societal issues.
   4. Focus on activity based, discovery learning strategies.
   5. Include coverage of the unique needs of women and minorities in the science and mathematics classroom.
   6. Incorporate field trips to sites which demonstrate the application of science to technology and societal issues.
   7. Prepare teachers to teach science and mathematics in language arts and social studies through the use of interdisciplinary modules created in the methods courses.
   8. Prepare teachers to become computer literate and to infuse computers into the elementary curriculum.

C. Extensive field experiences will be created for preservice elementary teachers.
   1. Three professional development schools will be created to function as clinical field experience sites.
   2. Field experiences will be planned to begin in the sophomore year and continue throughout the student's teacher preparation program.
   3. Professional development objectives will be developed to guide field experience expectations.
   4. Evaluation criteria will be established representing both generic and specific teaching skills in science, mathematics, and technology to assist in the systematic evaluation and monitoring of professional development objectives.
   5. Guidelines will be created to ensure the intensive supervision of field experiences provided by university specialists and public school practitioners.
   6. Field experiences will encourage students to practice techniques presented in content and methods courses as the students are introduced to these techniques.
   7. Field experiences will include opportunities for undergraduate students, practitioners, and specialists to conduct applied education research in the professional development schools.

  8. Mechanisms will be created to field test recently developed science, mathematics and computer curriculum in professional development schools.
  9. Seminars will be developed to involve students, practitioners, and university specialists in planning, implementing, and evaluating field experiences.

D. Content courses will be integrated with methods courses and field experiences.
  1. Science and mathematics methods courses and field experiences will be developed to focus on the domains of life science, physical science, earth/space science, mathematics, and interdisciplinary science/mathematics to correspond with content courses.
  2. Science and mathematics methods courses will be conducted in conjunction with corresponding content courses.
  3. Content courses, methods courses, and field experiences will be planned to cover the same content themes and encourage the same effective instructional strategies.
  4. Content specialists, methods specialists, and practitioners will meet during collaborative planning seminars to coordinate the preparation students are receiving.

E. Course materials will be created for content and methodology courses and field experiences.
  1. Course syllabi, lab manuals, student workbooks, and unit modules will be created for all content and methodology courses.
  2. Unit modules in interdisciplinary science and mathematics will be created for reading, language arts, social studies, and instructional technology methods courses (see appendix for example).
  3. Field experience guidelines, professional development objectives, and evaluation criteria will be developed for all field experiences.

YEAR 2-5 - Project Activities

Goal III: The KSU model program for preparing elementary teachers in science and mathematics education will be field tested, evaluated and improved.

Activities

A. The model program will be field tested as a training program using 26 elementary preservice students.

B. Formative and summative evaluation strategies will be utilized during the field testing phase to enhance the effectiveness of the program.

C. Evaluation results will be used to make necessary improvements in the elementary preparation program.

D. Evaluation data will broaden the knowledge base concerning the preparation of elementary teachers for effective science and mathematics instruction.

E. Course materials for content, methodology courses, and field experiences will be revised.

Goal IV: KSU will institutionalize this model program into the permanent curriculum of the College of Education.

Activities

A. The model program will be incorporated into the existing elementary teacher preparation program.

B. Newly created content and methodology courses and field experiences will become part of the required program of studies for elementary certification.

C. Permanent linkages will be maintained between university content specialists, education specialists, and public school practitioners through ongoing seminars.

D. The three professional development schools will be maintained through partnerships between KSU and the public schools.

E. Professional development schools will continue to be sites for field testing innovative science, mathematics, and technology curriculum and instructional strategies.

F. Inservice staff development opportunities for school practitioners will be maintained through partnerships between KSU and the public schools.

G. A permanent consultant panel will be established consisting of content specialists, education specialists, and public school practitioners.

H. Up to 200 students per year will be prepared as elementary teachers of science and mathematics based upon courses developed during the project.

YEAR 5 - Project Activities

Goal V: KSU will nationally disseminate a research-based preservice program for preparing elementary teachers in science and mathematics education.

Activities

A. The College of Education and the Center for Science Education will disseminate this program through the ERIC Clearinghouse, state and national conference presentations, and state and national educational journals.

B. The first cadre of 26 students will be monitored to provide follow-up support and to collect additional evaluation data.

C. Doctoral students at KSU will be involved in the preservice program for elementary teachers and will serve as national agents of dissemination once they finish their doctorates and relocate in a variety of positions throughout the country.

D. The potential 200 elementary students who complete this preservice program each year will serve as agents of dissemination once they graduate and relocate as teachers throughout the country.

SPECIAL ISSUES IN TEACHER PREPARATION

PANEL SESSION 4: Underrepresented Groups in Mathematics/Science

SCIENCE FOR PERSONS WITH DISABILITIES

Gregory Stefanich and Beth Wright
University of Northern Iowa

DEVELOPMENT OF A NOVEL COURSE: *EQUITY ISSUES IN A TECHNOLOGICAL SOCIETY*

April L. Gardner and Michael K. Fitzgerald
University of Northern Colorado

COMMON SENSE RECRUITING, A FORMULA FOR SUCCESS: THE SLRP FORMULA

James J. Copi
Madonna University

UNDERSTANDING THE NON-ENGLISH SPEAKER IN THE MATH AND SCIENCE CLASSROOM

John J. Halcón
University of Northern Colorado

SCIENCE FOR PERSONS WITH DISABILITIES

Greg Stefanich and Beth Wright
University of Northern Iowa

The population of practicing scientists today reflects a serious underrepresentation of individuals who have had physical disabilities before or during adolescence. Studies indicate that frequently this situation is not due to a lack of ability or interest on the part of the students, but rather to inadequate science preparation in both elementary and secondary schools. There is a need to update individuals who have been actively supporting and participating in activities to insure that the rights of persons with disabilities are being responded to in our schools and educational institutions. In addition a national effort is needed to again bring these issues to the forefront. We must increase the pool of individuals who are attentive to the needs of the disabled.

The gifted person with disabilities has an additional compounding problem--that of his/her limiting condition. Gifted persons are in every disabled population. It has been suggested by Whitmore (1981) that a figure as high as 540,000 students who are both gifted and disabled in the United States is reasonable. In the past, services for these students have been primarily in the area of remediation resulting from their limiting conditions, not in the development of their talents and gifts. According to Eisenberg (1981), special educators believe that a disabled, gifted child would not be in special education. It appears that many gifted, disabled students are recognized only by their limitations, rather than by any gifts they may possess.

Redden (1979) investigated nationwide science opportunities for physically disabled youth. Results indicated that students with disabilities receive little science instruction, and what they do receive is not academically adequate to allow them to pursue science education or instruction in science-related fields as possible careers. The absence of appropriate science education for the disabled is further evidenced by the dearth of disabled persons within scientific fields.

Hoffman (1979), a meteorologist afflicted with cerebral palsy, concurred with this conclusion when he stated, "teachers will often let studies decline to a point that they think will be a level at which their physically handicapped students can perform" (p. 39).

Parents of the severely disabled often support this lower expectation of teachers for two basic reasons:

1. Lack of confidence that their disabled child may someday be able to find employment and become a useful part of society, and
2. Hesitancy to place increased demands on the child because they perceive much hard work and time, which deprives the child of time for leisure or physical therapy.

The tragedy of low expectations is explicitly expressed by Menchel (1979), a deaf physicist who stated that disabled youth do not enter science fields because, by the time they reach the high school grades, they have not had a science education equal to that of other children. When they enroll in high school science without the fundamental building blocks, they find it too difficult. They do not understand science or like it; thus, they will avoid it.

Rehwoldt (1979), a paraplegic chemist, further delineated the tragedy of low expectations by describing the lack of sufficient consideration given to providing a physical environment in which the disabled can participate. He (cited Rehwoldt & Samoff, 1979) stated:

> Most high school science laboratories are not constructed so that the orthopedically handicapped student can participate in experiments. Limited resources and a lack of imagination may have actually prevented handicapped high school students from experiencing science in a positive and constructively challenging fashion (p. 264).

This statement still is true of most elementary and junior high settings as well. Rehwoldt and Samoff (1979) agreed with Menchel (1979) and Hoffman (1979) in their perception of frequent underestimation of a handicapped person's ability by teachers, peers, and family. They state:

> Self-assessments are derived from past experiences and from judgments and expectations of teachers, peers, and family of the student's performance in various spheres of activity. The student's perception of various careers and post-secondary education, too, are strongly influenced by the view and beliefs of others (p. 264).

The preceding statements clearly illustrate areas of difficulty experienced by persons with disabilities. Those quoted are among those who, through exceptional ability and persistence, have pursued scientific fields in spite of these barriers.

Only in recent years have educators and researchers begun to look at the powerful and important aspects of emotional conditions and their effect on learning and potential. Two fields of recent research are applicable if teachers are to be successful in efforts to revise education of the gifted, disabled student--self-regulation and learned helplessness.

The organizational structure of American schools is largely teacher-directed and regulation comes from outside the learners. Students seldom practice self-regulation and are not often given an opportunity to examine what they know and how they know it. This is particularly true of disabled students. When these students are taught to depend on external regulation, they do not learn to switch to controlled processing when their automatic processing is not sufficient to accomplish a task. They tend to give up when they encounter a roadblock in learning or a social setting which has produced discomfort in the past. This dependency is a contributing factor to the underestimation of the gifted, disabled student by teachers, parents, and peers.

Learned helplessness is a trait characterized by self-expectations of failure and little persistence to achieve. First described by Seligman and Maier in 1967, it has been found to be debilitating for the individual to the point of encumbering him/her in school, social settings, and later in the work force. This is even more damaging to the disabled student. The lack of understanding of learned helplessness of the gifted student with disabilities by teachers and parents can lead to untold suffering by the many afflicted with this condition because of already low expectations and school-fostered dependency. These students feel less competent, which "results in performance deficits unrelated to actual skill deficits" (Butowsky & Willows, 1980, p. 411).

Students with disabilities often have limited opportunities to explore and investigate outside of a supervised setting. In many instances they are not exposed or allowed to actively investigate their surroundings or probe into equipment and materials to the same extent as students without disabilities. Many of the exploratory experiences of childhood and youth are lacking, these become barriers to later learning; particularly when the primary means of instruction are expository, verbal, or through print materials. As an example, consider the following paragraph and the questions which follow:

The skip was in the hack. The third man was in the chute. He held the hammer. The rock must draw the button to win the game. The third man pushed from the hack and released the rock. The speed was perfect. The sweepers heard sweep, stop, sweep, stop, sweep. The rock nicked the point at the eight foot. The game was lost. The sweepers were angry.

Where was the skip?
Who was in the chute?
What must the third man do?
What did the rock do?
Why were the sweepers angry?

To a person experienced in the game of curling this is an interesting description. However, to a person who is not familiar with the sport, it makes no sense, even though the passage is easy to read and the questions can all be answered correctly. In a similar context, many students learn the procedures for answering questions but develop no conceptual framework as a result of the lesson. This is a common experience for all students in science classrooms, but is much more acute and serious for those with disabilities and/or those who have cultural deficits. The cumulative effects often develop teacher resentment of the learners, considering them to be apathetic and lacking in motivation.

Recent reports in educational reform often speak to raising expectations through raising standards. Raising standards will do nothing for students who have not been provided with educational opportunities in situations in which they can participate and be successful. One cannot demand high expectations through higher standards. Just as in the case of respect, higher levels of cognition must be earned. They are earned through providing numerous opportunities for learners to engage in activities and lessons in which the learner is successful. Instruction must begin with where the student is at, and almost without exception in the case of disabled learners, must include multi-modality hands-on investigations which enable active cognitive processing through experiences. Persistence is a by-product of success. Success is internal and must exist in the mind and emotions of the learner.

Fundamental among placement issues raised in the literature was the use and interpretation of evaluation instruments. Indeed, the validity and reliability of tests used for classification and placement has been repeatedly challenged (Gartner & Lipsky, 1987; Stainback, Stainback, & Bunch, 1989; Wang & Walberg, 1988). Gartner and Lipsky (1987) described these tests as "barely more accurate than a flip of the coin" (p. 372). Additionally, classifications resulting from these tests have been characterized as inconsistent owing to varying evaluator interpretations, state eligibility requirements, and official test cut-off points (Bogdan & Taylor, 1976; Gartner & Lipsky, 1987).

Moreover, these classifications have been found to be stigmatizing, instructionally unuseful, and generally permanent (Lipsky & Gartner, 1989). Addressing the relative permanence of such classifications, Gartner and Lipsky (1987) stated that less than 5% of the students are declassified and returned to the mainstream of regular education.

In addition to the questioned believability of testing instruments and the alleged irreversibility, usefulness, and stigmatizing tendencies of student classifications, other placement problems evidenced in the literature review. These involved placement decisions. A disproportionately high number of male, minority, and lower socioeconomic class students are in the labeled, i.e., special education, and lower tracked groups. Conversely, these pupils are underrepresented in talented and gifted programs (Goodlad, 1987; Lipsky & Gartner, 1989; Oakes, 1986a). Additionally, "these differences in placement by race and social class appear regardless of whether test scores [or] counselor and teacher recommendations . . . are used as the basis for placement" (Oakes, 1986a p. 14).

Inconsistency in placement decisions along with earlier noted inconsistency in student classifications resulted in another criticism of the placement process. Some students, particularly those who are economically disadvantaged, have fallen through the classification and program eligibility cracks. These pupils have not been adequately served and have, thus, been victimized by a fragmented continuum of educational services (Commission on the Financing of Free and Appropriate Education for Special Needs Children, 1983; Reynolds, Wang, & Walberg, 1987; Will, 1986).

When compared with upper ability tracked and heterogeneously grouped classes, the educational quality in lower tracked, regular and special education classes was described as inferior, nonfacilitative of lifelong learning, and even growth retarding (Goodlad, 1987; Oakes 1986a, 1986b). More specifically, students placed in such lower tracked classes reportedly experienced a watered-down curriculum that was characterized by less direct instruction and access to knowledge, e.g., less synthesis and more memorization, along with fewer opportunities to learn, e.g., less homework and instructional time (Sizer, 1984).

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Furthermore, these pupils were noted to lack the benefits of teacher variety, educational goal clarity, and summatively evaluated curriculums (Gartner & Lipsky, 1987).

In addition to the above-described problems in educational quality, lower tracked regular and special education classes were depicted as having unfavorable climates. Succinctly, these classes were criticized for fostering negative self-fulfilling prophecies and attitudes toward school as well as for not fostering atmospheres wherein long-term friendships could develop (Freagon, 1989; Gartner & Lipsky, 1987; Oakes, 1986a).

Similarly and finally, special and regular educational professionals within the aforementioned dual system have frequently adopted mutually exclusive, competitive, and uncooperative attitudes towards each other. Restricted opportunity for all educators to pool expertise, problem solve, and complement instruction has resulted (Stainback, Stainback, & Bunch, 1989).

In contrast to the reported disadvantages of homogeneous and segregated classroom arrangements, many advantages associated with heterogeneous and integrated arrangements manifested in the literature review (Stainback, Stainback, & Bunch, 1989, chap. 1).

In integrated educational arrangements, each child's unique instructional needs could be addressed through a continuum of programs "options available to every student" (Stainback & Stainback, 1984, p. 107). "Eligibility for educational and related services . . . [would] be based on the abilities, interests, and needs of each student as they related to instructional options and services" (Stainback, Stainback, & Bunch, 1989, chap. 2, p. 20). Pupils experiencing learning problems but not meeting current eligibility criteria would be served (Will, 1986) because they would have educational "rights without labels" (Gartner & Lipsky, 1987, p. 387). And, "it seems logical to assume that an educational system that is equipped to deal with major student differences will also appreciate and be able to deal with relatively minor differences" (Brown et al., 1979, p. 12).

"Recent research and experience have . . . demonstrated that, when given individualized, adapted, and cooperative learning programs, all students can be provided and opportunity to achieve their potential in integrated settings" (Stainback, Stainback, & Bunch, 1989, chapter 1, p. 3). For elementary students with and without disabilities, flexible and adapted integrated classes have been preferred to segregated classes owing to the academic benefits afforded by such environments (Dawson, 1987; Oakes, 1986a). Furthermore, disabled students in integrated programs have shown significantly greater reading and comparable math scores than their counterparts in segregated programs (Wang & Birch, 1984; Wang & Reynolds, 1985). Dawson (1987) explained that both high- and low-ability regular education students experienced greater academic achievement when in classes with more than 33% high-ability and less than 33% low-ability students than vice versa.

Not only have integrated arrangements been supported on academic bases, they have been supported on affective bases, as well (Oakes, 1986a, 1986b, parts 1 & 2). McDowell (1986) noted that when instructional environments are adapted to support diversity, "all students of all ability levels can achieve more . . . personally and socially" (p. 14). This personal and social growth has been reflected in the improved self-concepts and attitudes toward learning of handicapped and nonhandicapped, elementary and secondary students (Oakes, 1986a, part 1). Integrated settings provide opportunities for students to interact and experience unconditional acceptance, friendship, and interdependence (Stainback, Stainback, & Bunch, 1989, chap. 1).

A final benefit impacts the local communities that support integrated schools. As noted earlier, operation of the dual system of regular and special education poses not only educational but economical disadvantages. Succinctly, integrated environments favor less formal and timely instructional assessment over more formal and timely eligibility assessment. They also support coordinated acquisition and use of resources and services. Integrated educational arrangements were found beneficial to regular and special education students and staff as well as to the communities in which they live. Rather than receiving individualized tutelage contingent on classification, all students can receive instruction tailored to their needs, abilities, and interests in integrated settings. These settings were additionally found to further the academic and affective development of all students. A further consideration that extends beyond the direct educational realm is the school support. It is crucial for the full development of potential of this special population. It is the conclusion of some researchers that, due to the lack of such support by the school system, many gifted students (including the disabled) have been ignored or have fallen between the cracks (Newland, 1976). Newland felt that the result of this lack of such support is that gifted students become disenchanted with the system and many drop out academically and/or physically, or show recurring misbehavior.

Paradoxically, some gifted students with disabilities simply may become compliant with the system and suppress their giftedness.

One cannot just be concerned with the student's disability or giftedness. It is important to view each as a whole person with emotional, social, and physical needs. An important support person is the counselor, who should play a meaningful role in supporting and nurturing the emotional needs of all students, and must be informed about the nature and needs of the gifted students with disabilities. It appears when counselors do talk to the adolescent gifted student, it is usually about class scheduling or college preparation information, not about emotional needs (Clark, 1983). Leroux (1983) stated that bright students sometimes stay away from counselors because they are not trained in how gifted students feel or about their unique needs. As a result, these special students can be without the support they need to combat the feelings of loneliness and to cope with low self-concepts.

The active collaboration of a team of educators, each lending his or her special expertise, is critical if we are to effectively serve the gifted student with disabilities in the science classroom. When one looks at today's secondary schools with their departmentalization, administrative hierarchies, and large physical plants, it is easy to assume that someone else is responsible. Many of the special adaptations are subject-specific, requiring cooperation of the classroom teacher and other specialists. Teachers serving gifted students must assume an active role in bringing all of the parties together for the disabled gifted student.

A failure to respond is a severe loss to both society and the individual. Many disabled gifted individuals find themselves trapped in occupations which are totally inappropriate for their talents and abilities. We have a human and constitutional responsibility to all of our citizens.

Primary focus areas which are needed include:

-to provide an assessment of the current state of conditions concerning science for the disabled

-to make recommendations to federal, state, and local agencies, institutions and organizations for science education in careers in science and related fields for disabled students

-to accentuate the need to provide support services and assistance to all students within the regular classroom

-to insure the curriculum is adapted, modified and expanded to meet the needs of all students by varying instructional practices and objectives within any given lesson

-to encourage interdependence, cooperation and collaboration of staff and students through networking

-to increase awareness of technological advances and contributions which can enhance and contribute to the learning and participation of disabled students

-to ultimately affect the quality of science education for all disabled students

To better serve this often neglected sector of the school population, it is imperative to become aware of some of the characteristics of several gifted populations with disabilities. Each disability has its own unique needs and available resources. Three types of disabilities will be briefly discussed: (a) the visually impaired, (b) the hearing impaired, and (c) the orthopedically impaired.

According to Maker (1977) visually impaired gifted students appear to reach their potential and accomplish the same levels as the sighted. She also found that meaningful verbal memory was weaker than the non-disabled student. After interviewing gifted visually disabled persons, Maker learned that their desires were to experience a less protective environment and to be given more opportunities to explore, using their other functioning senses.

Those who teach the visually impaired need to become familiar with methods and services from The American Printing House for the Blind, P.O. Box 6085, Louisville, KY, 40206; and instructional aids and materials produced in Science Activities for Visually Impaired/Science Experiments for Learners with Physical Handicaps (SAVI/SELPH), Center for Multisensory Learning, Lawrence Hall of Science, University of California, Berkeley, CA 84720.

Several teaching considerations that would be beneficial to these students are to provide opportunities to work in small cooperative groups with supportive sighted partners: provide oral directions, either through direct instruction, or by a recording device; if necessary provide Braille materials; and print large forms and instructions.

The gifted hearing impaired, according to Maker (1977), experience a slower rate of development and have greater difficulty dealing with abstractions than the non-impaired. Materials and services from the Alexander Graham Bell Association for the Deaf, 3417 Volta Place NW., Washington, DC. 20507 would be useful for teachers to better serve this population. It is imperative that the child be in good visual contact with the instructor, and the instructor use appropriate gestures and body language. If necessary, obtain a person who is competent in sign language to aid the student in class. Because the student has difficulty with abstractions, the teacher should use concrete objects whenever possible.

Orthopedically impaired gifted students, notes Maker (1977), usually do not lag behind their non-disabled counterpart in cognitive maturity. However, they do require some special considerations when in the classroom and, more importantly, support from educators to ensure that they receive educational experiences commensurate with their talents and abilities. An important resource is the National Center on Educational Media and Materials for the Handicapped, Ohio State University, 154 West 12th Avenue, Columbus, Ohio, 43210. Changes in the physical arrangement of the room and laboratory may need to be made to accommodate their special needs. To compensate for the physical limitations, pairing a physically-abled student with the impaired student to work cooperatively allows for more exploration.

There is considerable evidence that cooperative learning arrangements permit more positive relationships for all students than do competitive, individualistic, or traditional lecture-recitation instructional lessons. Students are best served when teachers understand their obligations and responsibilities, and serve as reliable sources of support.

Often students with disabilities have fewer interactions in social contexts. School settings which necessitate interactions with others are important. Good teachers are constantly in search of opportunities to integrate socially isolated and withdrawn students into cooperative activities. Everyone needs to feel important, appreciated, and included. Quality with equity requires that all students are given equal access to educational endeavors. This must include respect for the unique physical, social, emotional, and academic attributes of every child in a context of inclusion.

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DEVELOPMENT OF A NOVEL COURSE: *EQUITY ISSUES IN A TECHNOLOGICAL SOCIETY*

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Rationale & Objectives

One primary goal of the UNC Pre-Service Elementary Mathematics and Science Teaching Project was to sensitize prospective elementary teachers to the fact that certain groups (females, ethnic minorities, and physically-challenged individuals) are underrepresented among mathematicians, scientists, and engineers. Furthermore, we wanted future teachers to develop and practice teaching strategies that have been shown to stimulate interests and achievement related to science and mathematics among students in these groups. We addressed this goal through development of a three-hour course, *Equity Issues in a Technological Society*. Project students enrolled in this course their first semester on campus, concurrent with the *Earth Science Concepts for Elementary Teachers* course (see Jay Hackett's paper from Panel Session 1). As noted previously, the first group of project students enrolled in Fall 1988 and the second group the following year. Each group included 60 to 65 beginning college students.

Approaches

Specific objectives of the *Equity Issues* course were to: 1) raise students' awareness of, and sensitivity to, inequities that exist in our society, particularly regarding participation in mathematics, science, and other technology-related fields; 2) explore possible causes of these inequities; and 3) develop and practice teaching strategies to minimize these inequities. From the beginning, we were determined to uphold another primary goal of the project: to model teaching consistent with constructivist theories of learning. Recommended teaching strategies included an inquiry-oriented approach and the use of cooperative learning groups. In addition, we intended to model approaches especially unique to "equitable" teaching, such as the use of role models and gender-unbiased language.

As reflected in the syllabus for the Fall 1989 course (see Table 1), the discovery approach is emphasized by use of focus questions for daily topics;

Table 1
Fall 1989 *Equity Issues* Course Syllabus

EQUITY ISSUES IN A TECHNOLOGICAL SOCIETY
Fall 1989 Course Syllabus

Day/Date		Focus Questions
Introduction to Course:		
Th	8-31	What do we mean by "equity"?
T	9-05	What is the scientific method &
Th	9-07	how does it relate to equity studies?
T	9-12	Who are we concerned about in
Th	9-14	mathematics & science? Why?
Females and Mathematics/Science:		
T	9-19	Why are there gender differences
Th	9-21	math & science achievement?
T	9-26	What happens outside school?
Th	9-28	What happens inside school? I
T	10-03	What happens inside school? II
Th	10-05	What happens inside school? III
T	10-10	How does the "classroom culture"
Th	10-12	affect learning by all students?
T	10-17	Review for exam
Th	10-19	MIDTERM EXAMINATION
Minorities & Physically Disabled and Mathematics/Science:		
T	10-24	What additional factors affect
Th	10-26	science and mathematics learning by
T	10-31	minority children?
Th	11-02	How can teachers make science and
T	11-07	mathematics relevant to
Th	11-09	minority students?
T	11-14	How can teachers encourage math and
Th	11-16	science interests among physically disabled students?
T	11-21	How can teachers encourage extracurricular sci/math experiences among students?
Th	11-23	THANKSGIVING BREAK
T	11-28	Student Projects
Th	11-30	Student Projects
T	12-05	Student Projects
Th	12-07	Review for final exam

course content is also indicated in these questions. During the first two weeks we introduced the concept of "equity" and provided a general overview of equity issues surrounding mathematics and science education and careers. Approximately half the course was devoted to in-depth consideration of females in science-related areas; slightly less was devoted to minorities in these fields; and approximately one week to physically disabled persons in science and mathematics areas. There was no text for the course; instead, a collection of articles and book chapters complemented each topic introduced in class meetings.

An example of the discovery orientation of the course is the "Toy Ads" activity. As an introduction to causes of gender differences in science/mathematics interests and achievements, students in cooperative groups examined a variety of toy advertisements that depicted children playing with toys. Each "ad" was scored for the type of skill it would develop among children (nurturing, sports, mathematics/spatial skills, future job, homemaking, or language skills) and the numbers of girls and boys shown with the toy. Finally, students graphed their results and we discussed what they had observed (a sample graph is shown in Figure 1). This comparison surprised many students--they were amazed to discover that more boys than girls in general were shown playing with toys and that toys that develop mathematics, spatial, sports, and future jobs skills in particular were shown more often with boys than with girls. We were able to sensitize students to ways that the popular media influences children's (and adult's) beliefs about what are appropriate activities for males and females. This activity was followed by a reading assignment on the influences of "boy" and "girl" toys.

Students also read articles about subtle inequities in classroom interactions, and they reflected on their own experiences in elementary, middle/junior high school, and senior high school (they kept a journal in which they recorded their responses to class discussions, activities, and readings). Students' understandings and experiences of inequities became the basis of small group and whole class discussions. Other class assignments extended this topic. Each member of a cooperative group interviewed elementary students and/or teachers about their attitudes toward the fields of mathematics and science or toward scientists and mathematicians. Interview results were compiled into a joint report of the groups' findings. Each student also visited an elementary school to observe an elementary mathematics or science lesson.

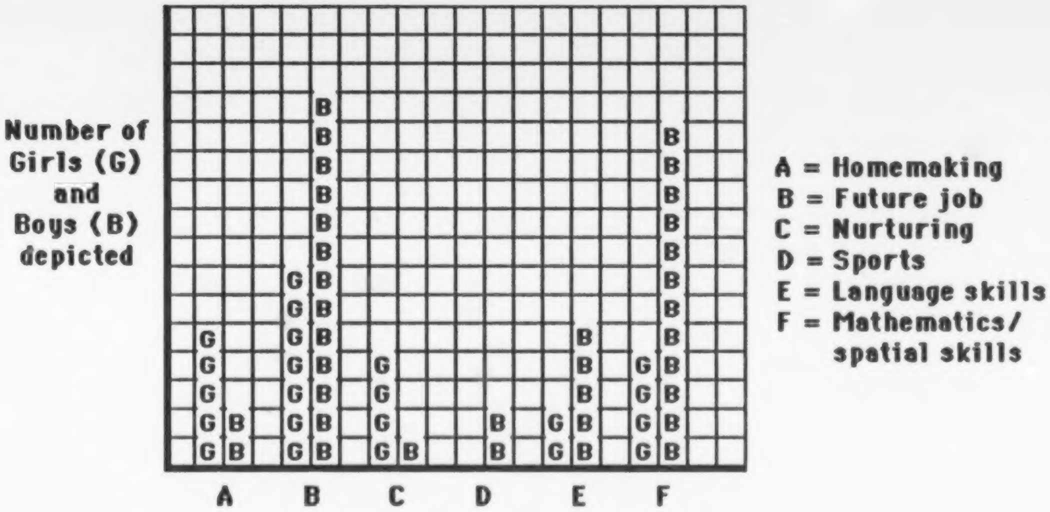

Figure 1

Sample graph from the "Toy Ads" activity.

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Table 2

Sample *Equity Issues* examination questions.

- In the article "The Disadvantaged Majority: Science Education of Women," Jane Butler Kahle describes societal, educational, and personal factors related to girls' negative attitudes toward and lower achievement levels in science. She goes on to describe seven classroom strategies which could help remedy this situation. List and describe three of these strategies.

- Recall the article "Educating Poor Minority Children" by James Comer and the videotape we viewed on Blacks in science and mathematics. Several ways for schools and communities to improve the educational program for poor minority students were outlined. List 5 of them.

- In the article "Doing Science with Handicapped Students and the Gifted," Mary Budd Rowe comments that there is one variable which distinguishes the learning behavior of physically disabled or emotionally disturbed children from non-disabled children. Name this variable and explain why it is important for learning by one group of disabled children (blind or wheel-chair bound or emotionally-disturbed, etc.).
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Group members pooled these observations into a report relating both equitable and inequitable interactions and teaching strategies they observed. The final class assignment required cooperative groups to develop a short, equitable science or mathematics lesson and teach it to a group of elementary children. A peer group observed and evaluated their lesson for equitable teaching strategies.

The course grade was based on projects such as those described above, attendance and participation in class discussions, and a midterm and final examination. The examinations were composed of essay/short answer questions based on reading assignments, class discussions, and class activities. Sample questions are shown in Table 2.

Outcomes/Effectiveness of Approach

The effectiveness of the *Equity Issues* course in meeting project objectives was assessed using both quantitative and qualitative methodologies. A comparison group of 60 students was recruited from prospective elementary teachers enrolled in non-project sections of other elementary education courses. (The *Equity Issues* course was not offered to non-project students.)

Quantitative evaluations included a comparison of project and control group students' pre- and post-test scores on two survey instruments, the *Occupational and Educational Information Instrument*, which examined students' awareness of the status of women, minorities and the physically disabled in science and engineering fields, and the *Teacher Behavior in the Classroom* survey, which examined students' awareness of typical teacher behaviors toward male and female students. Both instruments were developed within the project; sample items for each are shown in Table 3.

The pre-test was administered at the beginning of students' first semester on campus; the post-test was administered at the end of the semester. In addition, project and control group students were periodically asked to list "as many teaching strategies as you can think of to ensure that all students participate in, become interested in and learn from science and mathematics and other subjects." The listed strategies were scored for those considered to be examples of equitable teaching (coding was based largely on a list of equitable teaching strategies developed by project staff and students).

Project and control group students had similar pre-test scores on the two instruments; project, but not control, students' scores increased significantly with time (Constas, McDevitt, & Gardner, 1991). Project students also listed significantly more equitable teaching strategies than did control group students, even at the third administration of this test, over a year after completing the *Equity Issues* course.

Perhaps more profound results were obtained from the qualitative evaluation of students' understanding of equity concerns (Constas, Gardner, McDevitt, Heikkinen, & Horton, 1992). Project and control group students were interviewed at the end of the Fall Semester, 1989. The first project group had completed three semesters in their teacher education programs, including the *Equity Issues* course, while the second project group had completed just one semester, which also included the *Equity Issues* course. They were asked two questions relevant to the course: "What is equity?" and "What does it mean to teach in an equitable fashion?" Interviewers reported that project students readily responded to the first question, while control group students required considerable probing and prompting (what is fairness?; what does that mean for a teacher?).

Interviewers also noted qualitatively different responses to the questions. Responses of the 1989 cohort of project students (who had completed just one semester of university study) fell into three categories. The greatest number of responses were categorized as **theoretical**--equity as an abstraction or ideal to be achieved. A typical student response from this category was: *Fairness in dealing with people in a fair and unbiased way. I think it is a really good topic that needs discussion because everybody has a bias.*

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The second most frequent category of responses was termed **practical**--equity described as a concrete set of activities or actions to be achieved. A typical student response was: *Mix them up in the classroom so you don't have boys on one side and girls on the other.* The least frequent responses fell into the **uncertainty** category, representing confusion about the meaning of the term "equity." A

Table 3

Sample items from the *Occupational and Educational Information Instrument,* (OEII) & the *Teacher Behavior in the Classroom* (TBC) survey.

OEII–Multiple Choice Items

- Women make up 45% of all employed workers. What percent of employed scientists are women?

  a) 25% b) 35% c) 45% d) 55%

- About 7% of the US. civilian labor force is Hispanic. What percent of scientists and engineers is Hispanic?

  a) less than 1% **b) 2%** c) 7% d) 12%

TBC--True/False Items

- Sex-role stereotyping has now been eliminated from elementary textbooks and tests. (false)
- Boys receive more praise from teachers for academic performance than do girls. (true)

typical response was: *Everybody asks me that and I still haven't figured it out. I don't know. It's just a class I have to take for a program I am in . . .* "

Responses of the 1988 cohort project of students fell into the theoretical and practical categories only; their most frequent responses were in the practical category. Differences between the two project groups may be due to maturational differences, but it could also be the result of students' attention to equity concerns in subsequent courses and field experiences after initial sensitization in the *Equity Issues* course.

Recommendations

One of our initial concerns was the timing of the *Equity Issues* course. Would it have been more appropriate to require this course later in the program, when students would be able to draw from their own college mathematics and science course experiences? The outcomes described above, and feedback from project students themselves, have convinced us that early exposure to these issues is critical. Among the documented benefits of sensitizing students to equity concerns early is that students carried the concerns to their other courses and became change agents among the diverse faculty teaching those courses. Furthermore, their early sensitization was reinforced through field experiences. One project evaluator noted that project students' reports of field observations nearly always mentioned inequitable teaching, a rare comment in control group students' reports.

There are many alternative ways to accomplish the equity awareness goal. In this project, an early course specifically devoted to equity issues in mathematics and science education, was followed be other science, mathematics, methods, and education courses that also address these issues. The *Educational Psychology* course addressed equity in mathematics and science specifically (see Jeanne Ormrod's and Kathryn Cochran's paper from Panel 2) and a mathematics course used the Mayan system to introduce numeration, rather than the traditional Arabic system (see Chuck McNerney's paper from Panel 1). The highly successful teaching seminars that accompany science courses developed in the University of Wyoming program (see Joe Stepans' paper from Panel 2), offer an excellent way to reinforce equity goals throughout a teacher education program. We believe that a specific course that focuses attention on the issue early should be considered; however, this may be accomplished in a one- or two-hour course, rather than a three-hour course. Informal discussions with project students indicate that they also believe early exposure to equity concerns is important, but some students recommended a "return to equity issues" toward the completion of their program.

Finally, we offer a few recommendations about the instructional format of the course. We propose that the inquiry-oriented approach is essential. Students "discover" inequities for themselves and become committed to eradicating them; we believe that a lecture approach would put students on the defensive and make them much less likely to adopt the concerns as their own. This implies designing activities in which students explore equity issues, such as observing actual elementary classes and testing potential activities for the elementary classroom. Course instructors must arrange for student visits to local classrooms. This was facilitated in the UNC project by mentor teachers (see Bj Stone's paper from Panel Session 6), who recommended and helped arrange for visits in their home districts. In addition, the class should not be conducted in a lecture room; the classroom must have movable chairs and desks. Furthermore, the discussion and activity emphasis of the course requires small to moderate class sizes--we recommend no more than 35 students per section.

In conclusion, our experience with a novel course on equity issues in mathematics and science education suggests that it is an extremely effective way to sensitize prospective teachers to these concerns. Whether or not it has an impact on actual teaching behaviors will await project students' entry into the field in the next few years. We hope to follow some of these students into their first teaching assignments to determine the impact of project experiences on their classroom behaviors.

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COMMON SENSE RECRUITING, A FORMULA FOR SUCCESS: THE SLRP FORMULA

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Implementation of the Recruitment Program

The success of any recruitment effort requires a substantial commitment to each component of the SLRP (Student, Location, Resources, Presentation) formula described below. Some components may require more attention than others, but none can be ignored without dramatically influencing the others. They are interrelated and can be managed into an integrated, successful recruitment venture.

Students. The students one wishes to attract into a program most probably belong to certain under-represented groups. A good listing of characteristics for teacher education students in general, and for students from several ethnic groups in teacher education programs, is provided in "Recruiting Minority Teachers" (AACTE, 1989). This list provides a resource for developing an assessment of the traits for one's own target group. For example, teacher education students have a greater tendency to engage in extracurricular activities in high school and to recommend their college/university to others. If one's interest is the recruitment of minorities, the North Central Regional Educational Laboratory has gathered and disseminated information (NCREL, 1990). This midwestern publication suggests early identification of youngsters interested in teaching, improving counseling for minorities in high schools, designing teacher preservice programs, etc. Recognition of the need to involve more individuals from under-represented groups, including the disabled, in science teaching has been addressed by the American Association for the Advancement of Science (AAAS, 1990). Recommendations/suggestions included the strengthening of academic support services, providing more opportunities for research and applied learning experiences, and making special provisions for the disabled and physically handicapped. It was not mentioned in this report, but it was certainly implied, that special provisions need to made for hearing-impaired students (notetakers, interpreters, closed captioning).

Location. The location and distribution of the target group will influence the utilization of available resources. The success of the integration of the efforts employed will depend upon the feasibility of expeditiously arranging schedules and visitation routes to the areas of concentration, the dissemination of materials, and the eventual accomplishment of the recruitment efforts.

Resources. Any recruitment effort has available a wealth of institutional and community resources to manage. The institution already has recruitment strategies in place (open houses, school visits by recruiters, campus visitations by students, participation in college nights at schools, showcases, audiovisual presentations) which reinforce word-of-mouth acknowledgments of the merits of your program to potential students. It is especially helpful if the recruitment personnel includes a minority who is an alumnus of the institution. A number of retention strategies are also important to include: competent pretesting for determining academic potential so as to provide appropriate advising, tutoring, counseling services, academic planning and career preparation, personal contact by faculty, mentors, a student retention office, an ESL (English as a Second Language) office, a multicultural affairs office, and the availability of constructive role models. The accessibility of financial assistance is vitally important to many students. The personnel need to be friendly, helpful and competent. The institution needs to make a firm commitment toward the success of fund- raising resources. Many students require personal assistance with the filling out of forms (including knowing which forms to fill out, how to fill them out, when to fill them out, and where to turn them in). Students need to be made aware of what scholarships are available and how they can apply for them. Personal experience indicates that minority students need additional encouragement to complete all necessary paperwork and provide all necessary documentation. They must be made aware that all students are required to follow rather stringent procedures according to regulations and stipulations placed upon the financial aid office from external agencies. The students must understand that they are not being harassed and that some sensitive information must necessarily be divulged in order to provide appropriate assistance.

The institution can provide additional assets that affect the program. An important resource is the public relations/publicity office that announces programs via various media outlets (newspapers, radio and television stations), special events, and featured articles and complementary photos. The faculty can become involved in special assignments for developing new teaching techniques that enhance learning and retention. Strategies can be developed for incorporating discovery learning, team-building, new technologies (e.g., interviews and workshops that sensitize faculty to the most effective methods facilitating the success of minority students. The institutional support staff must certainly be included for the success of your program. The key person is the program/department secretary, whose demeanor, organizational skills, reliability, and commitment are essential for the smooth management and operation of the program. Office aides and clerks also need to show students that they are eager to provide assistance that is truly helpful. The maintenance and janitorial staff are accountable for a clean and well-maintained physical plant and grounds that provide a good first, and lasting, impression for potential students. All of these persons are responsible for subtle, subconscious indications of the caliber of your institution and your program. Their cooperation is another important element in successful recruitment.

A number of community resources are worthy of receiving information so they can support, recommend and promote your program. Members and leaders of ethnic organizations can provide community exposure via meetings and publications. School personnel can include teachers, counselors, principals, superintendents and school board members, who can all contribute support and help spread the word about the program. Businessmen, teachers and other professionals can become mentors and maintain personal attention and concern for individual students. Churches can also focus on your program through their dispensation of information which serves to improve the community and create career awareness via assemblies and publications (e.g., a weekly church bulletin).

Presentation. An essential element of the success of one's recruitment efforts is the capacity to inform potential students of the existence of the program, to convince them that it is worthwhile and attainable, and to have the majority of them successfully complete the program. Information about one's program can be disseminated by a variety of methods. Publicity via media resources (newspapers, television, radio) can be directed to reach a large ethnic or minority audience. In-house publications can keep undecided students and academic advisors informed in your institution. An attractive brochure/pamphlet can be developed to provide essential information (phone numbers, contact persons) without overwhelming potential students with too much material. It should provide interested persons with a mail-in section for them getting further information and for their inclusion on a mailing list. Send personal letters to all potential students expressing an interest. Include a letter to students currently in related programs. For example, when developing science teachers for elementary and middle schools, a letter can be sent to each student currently in your education programs. Some of these students may elect to change their focus and enter the program being promoted. Include an invitation to attend your Summer Vestibule Program (described below), and encourage students attending former summer vestibule programs to return. The discussions that will naturally occur between current and potential students can be invaluable. Visitations to high schools, community colleges, and community groups can be conducted by recruitment personnel, faculty, current students, and alumni in order to deliver first-hand information to potential students, teachers, counselors, and community leaders. A timely newsletter can keep all interested parties informed about changes in the program, employment possibilities, changes in institutional policies, highlights of students in the program, interesting facts about faculty, and updates about the next summer vestibule program.

Part of the program could include a Summer Vestibule Program that allows potential students the opportunity to visit the campus in order to become familiar with the institution, the program, and with potential colleagues. It should incorporate a wide variety of experiences which cultivate familiarity and initiates bonding processes (short tours of facilities, hands-on science activities, field trips, role models as guest speakers, videotaping of a master teacher in action, information sessions with Admissions and Financial Aid staff). Participants should be made aware of available support services (tutoring, mentors, retention office, ESL office, multicultural affairs office). Make the program informative, fun, and at no cost to the student. The summer vestibule program has been most successful at Madonna University as two parallel one-week sessions of twenty hours duration each from Monday through Friday for four hours each day. The sessions for one week meet mornings with the parallel session meeting in the early evening during an adjacent week, in an attempt to accommodate different work schedules. A summarized five day schedule is as follows: Day 1 - Welcome and Introduction to Project STEP; Tour of the Science Wing; Hands-on Classroom Activity ("The Hungry Flask" - a simple oxidation reaction); Madonna Pond Study - water and bottom sampling, feeding and seining fish, observing aquatic vegetation and wildlife; microscope study of pond life; SUCCESS sessions on "How to Succeed in College", "How to Prepare For and Take Exams". Day 2 - Lab Activity ("Toying with Physics"); Concrete and Formative Knowledge Testing for determining academic readiness; Computer

Lab Activity (manipulating variables to maximize plant growth using "Botanical Gardens"); SUCCESS session on "How to Succeed in College Courses" for developing learning and critical thinking skills. Day 3 - Tour of the Education Department to meet faculty and staff; observing the videotaping of a master teacher instructing children in science concepts; making "slime" with children in the lab; more SUCCESS sessions. Day 4 - field trip to a local metro park with a variety of habitats. Day 5 - Participant Recognition Day: inspirational guest lecture; awards - announcement of STEP scholarship recipients, certificates of participation; science show as entertainment; group picture; refreshments with faculty, administrators, staff, and family members.

Suggestions

Recruitment success or failure is largely dependent upon expectations associated with the attainment of realistic goals. Some additional recommendations for action can be appropriately categorized and listed as do's and don'ts.

Recruitment do's. Do reveal the entire program to inquiring students. Include all of the curricular requirements so that the expected level of their commitment to the program is revealed. Do spend quality time with prospective students by answering all of their questions, giving them a tour of the facilities, and introducing them to faculty and staff so that they know you consider them to be special to everyone associated with the program.

Recruitment don'ts. Do not promise what you cannot deliver (scholarships, placements, jobs). Do not become overly influenced by recruiting goals. For example, do not set unrealistic quotas which distort recruitment priorities. Unreasonable goals ultimately lead to increased attrition in programs because students were coerced into the program in order to meet allotments.

Instructional do's. Do teach your students science in the way that you would like them to teach science to their students in the future. Do make science courses interesting, challenging, and fun for your future science teachers so that they can do the same for their students. These two suggestions can be addressed by the modification of instructional techniques incorporating laboratory and field activities that can be more readily adapted to the actual classroom that the future science teacher will experience when they enter the profession. Most contemporary college/university science laboratory experiences utilize expensive and sophisticated techniques and instrumentation which would be an unrealistic approach to the actual classroom environment encountered in most K-12 classrooms.

Do incorporate meaningful orientation sessions to the program via a campus visitation, such as a summer vestibule program. Do increase the accessibility of knowledge for all students by using the latest instructional technology and by making adjustments for each specific group of students to maximally benefit their experiences, such as mentorships, tutoring, and special activities. Do expose students to the actual classroom experience in the K-12 schools as early as possible in the curriculum, which can be one of the objectives of their first education course.

Advising do's. Do be sincere with your students by showing them that you really care about their participation in the program. Know them by name, greet them in the corridor, plan their participation in special events, and maintain personal contact with them at times other than scheduling for classes. Do show students that you are able to act in their best interest, which means that you may need to act as an ombudsman to expeditiously solve problems.

Evaluation do's. Do measure successes as outputs: grade point averages, school placements, certificates issued, eventual success in securing teaching positions. Also explore more qualitative methods of evaluating students success, such as: log/journal entries, yearly reflection summaries, and surveys that can identify the students' attitudes toward science, science teaching, professional development, etc.

This listing of suggestions is far from inclusive and is provided to assist in the development of one's own priorities. Other suggestions can be derived from Chubin (1990), who includes insights into recruitment by addressing misconceptions about scientists. His examples include fallacies that scientists are the smartest students who are risk takers that decided their career at a very early age.

Credits

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UNDERSTANDING THE NON-ENGLISH SPEAKER IN THE MATHEMATICS AND SCIENCE CLASSROOM

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Teaching math and/or science to limited- and non-English speakers poses significant problems to teachers because of the obvious language barrier. Since the overwhelming majority of teachers who encounter limited and non-English speaking children in their classrooms do not speak a second language, increasingly they are unable to provide quality instruction for their students. As a result, limited- and non-English speaking students are not performing up to their capabilities; not because they are unintelligent, or disinterested, but in fact because too often teachers simply cannot provide them with comprehensible input. Since teacher education programs generally do not require that future teachers learn a second language, given the rapidly changing demographics of the west and southwest, it is becoming increasingly clear that teachers are the ones who are experiencing a "language problem." Frankly, if our country is to reach its *America 2000* goals for mathematics and science learning, then meeting the needs of limited- and non English-speaking children becomes paramount.

In this paper, I will address briefly the issue of literacy in math & science instruction as it applies to limited- and non-English speaking children. I want to begin by focusing on two concepts: 1) literacy, and, 2) comprehensible input. Both impact, and are impacted by math & science instruction.

First, literacy refers to the ability to read, write, speak, and listen. This concept, however, is treated as if it were synonymous with English (Reyes, 1991). That is to say, teachers and the general public assume that when one speaks of literacy, one necessarily means English. These are not synonymous terms. This distinction must be understood clearly by teachers and others if we expect limited- and non-English speaking children to benefit from the educational system. Teachers, above all others, must understand that it is possible to be literate in languages other than English. It is also possible to be literate in math and science, and not speak English, *and* finally, it is possible to learn math & science in languages other than English. Additionally, let us not lose sight of the fact that it is also possible to teach English to limited- and non-English speaking students through math and science instruction (Cuevas, 1991). Too often, the fact that a particular teacher cannot speak a second language becomes the standard by which they judge speakers of other languages. This limited perspective on the part of the teacher is too often the basis for lowered expectations and the reduction of standards in classroom instruction. It is also the justification for ability grouping, where "like" students-defined as ethnically and linguistically similar students-are placed "for their own good". Inevitably, this is in the lower track.

Secondly, comprehensible input refers to the ability of teachers to communicate with children in a manner in which they can understand. As teachers, we assume that it is our responsibility to provide comprehensible input to enhance the child's learning. This means that instruction must be presented in a language a child can understand. Without comprehensible input, as we have all experienced, children will not learn--and we should not expect them to. Without comprehensible input, in fact, no learning can occur. Yet, the lack of comprehensible input is precisely why many limited- and non-English-speaking children have such difficulty learning math and/or science. Mathematics teachers, in particular, find it difficult to "implement with students who are not proficient in English" (Cuevas, 1991 p. 186). The typical teacher presents material to students in a foreign language, fully expecting them to comprehend. Then unthinkingly, or perhaps naively, when the students don't perform up to par, they blame the student, their culture, their family, or the fact that they don't speak English, for their own failure as a teacher, forgetting that responsibility for teaching lies with the teacher and not the student.

Literacy and comprehensible input are concepts which are fundamental to our understanding of the individual educational needs of limited- and non-English speaking children. These concepts are neither contradictory, nor are they at odds. In fact, there already exists a substantive literature which addresses them (Artzt, A. & C. Newman 1990; Randall, C., F. Lester and P. O'Daffer, 1987; Cuevas, G. J., 1990; Saville-Troike, M., 1984). If our goal as teachers, irrespective of our individual disciplines, is to promote effective communication skills and the ability to interpret and analyze scientific and mathematical concepts and data, then why do we insist that this learning must occur in English? The answer, of course, is ... it doesn't have to be.

Let me state my biases regarding forced instruction in English without comprehensible input--especially in the content areas. If a teacher knows that a child is a limited- or non-English speaker, why do they insist on testing them in a language that they already know the child does not understand? In the math and sciences, in particular, when teachers test limited- and non-English speaking children in English, are they not proving that, in fact, the child doesn't speak English rather than learning anything about their math/science skills? Could we not learn much more important information about their learning, and our teaching, if these children were tested in a language they understood and were given the opportunity to respond in their own language?

This is not an argument for or against the fact of English language instruction. No one will argue that all children shouldn't learn English. Most Americans understand that learning English is a requirement for successful entry into mainstream society. No, this is a call to teachers to accept responsibility for comprehensible input when they teach math and science to limited- and non-English speaking children. This is also a call to support the National Commission on Standards for School Mathematics who emphasize the importance and need to use math & science instruction not only to teach content in these subject areas, but also to teach English literacy (NCSSM, 1989).

Limited and non-English speaking children provide a wide-ranging array of problems to math, science and other teachers as we are all aware. These include some who (a) lack the ability to listen, speak, read or write in English, (b) understand English but are below grade level in reading and writing, and (c) have experiences with math and science which may range from very well-prepared (but not in English) to no formal math/science instruction in either language. Even the classroom context provides some interesting dilemmas. For example, some limited and non-English speaking students, especially immigrants, are accustomed to much more formal classroom environments.

In the case of those children who are relatively well-prepared in math or science, but not in English, they usually do well in computational skills, but when they reach word problems--they lose ground rapidly. In this particular instance, every rule of good teaching is violated. These children are learning computational skills, then when they are experiencing some level of success, teachers pull them away from a positive experience and toss them into a negative one. Its like tossing them into an uncharted ocean, without a compass, map, or life raft. We withdraw all semblance of comprehensible input. Literally, we force them to "sink or swim". Why?

If our goal is one of developing problem-solving skills, then what does it matter in which language this occurs so long as the child develops the skills?

Why do limited and non-English speaking children begin to fall off the boat? Because teachers act as if word problems can only be done in English. Why don't teachers have these word problems translated? Why aren't these kids allowed to practice their problem-solving skills in a language they understand? Better yet, why not use math and science instruction to teach English language skills as well? Given this context, how can limited- and non-English speaking children be assisted in developing the skills they need, including English language skills, to deal ultimately with the task and content required of math & science classes?

Suggested Instructional Strategies

Let me suggest several instructional strategies to facilitate the process of teaching mathematics to limited- and/or non-English speaking students that I have borrowed from Gilbert Cuevas which appeared in the March 1991 issue of *Mathematics Teacher*. While specific to math teachers, these suggestions are also apparent for science teachers.

Afford opportunities for students to clarify key terms and words. Because each word and phrase used in math & science requires a complete grasp of their meaning, "it is essential for students to learn key words and terms". Thus, "students need to be given the opportunity to read the terms and definitions". Cuevas (citing Krashen and Terrel-1983), talks about the importance of context in which the students will be using the new vocabulary. In this manner, "language can be made comprehensible through a variety of means, such as demonstrations, hands-on materials, visual aids, and manipulation of content." He also advocates that children be allowed the opportunity to ask questions about the vocabulary, use them in sentences, and where possible, describe them using visual or concrete examples. In addition, lessons that teach new concepts in mathematics should use graphics, manipulatives, and other hands-on, concrete materials that clarify and reinforce meaning in mathematics communicated through the non-English language.

Offer opportunities for students to talk about mathematics with one another, using their native language as well as English. Instruction in either math or science should be "structured to allow the children the choice of using the native language or English." Cooperative learning groups, providing that they are structured to include students with varying degrees of language proficiency (in both languages), "are the optimal setting for this type of discussion to occur." Citing research by Saville-Troike (1984), Cummins (1984) and Hakuta (1986) on literacy development and second language learners, Cuevas (1991) argues that concepts and skills can be reinforced when limited and non-English speaking children are given the chance to discuss them in their native language.

A hands-on approach to science learning such as that provided by *Finding Out/Descrubrimiento* allows for children to help each other to accomplish the objectives for each task. This cooperative approach not only accomplishes the conceptual learning objectives in science & math, but also significantly improves the English proficiency of limited and non-English speaking children in the groups (DeAvila, Duncan & Navarrette, 1987). Instructional activities should promote second language development through a natural, subconscious process in which the focus is not on language per se, but on communicating the concepts, processes, and applications of mathematics and science.

Maintain a classroom climate in which students with limited proficiency are encouraged to participate. Do not shut them out because their grammar is not perfect. Literacy occurs only when children use language. In essence, one becomes proficient in a language over time, in a cumulative fashion, and with repeated use of the language. According to Cuevas (1991) "an essential part of the process of learning the language is to give students the freedom to make errors when speaking English." Grammatical errors should be treated in a tactful manner, and should not become the basis for unnecessary stress or tension. In other words, it is not necessary to make "mountains out of molehills" when non-English speakers make grammatical errors. Appropriate grammatical structures can be modeled rather than punishing non-English speaking students if they make what for English speakers would appear to be "simple" mistakes. It is important for teachers to understand that, generally, grammatical errors are irrelevant to problem-solving in math or science.

Additionally, appropriate translation of the material *beforehand* can help with the comprehensible input necessary to reinforce mathematical concepts in the child, and to avoid risk of injury in science experiments.

Give students opportunities to examine and discuss problem-solving processes. According to Cuevas (1991), by verbalizing problem-solving processes in either language, limited and non-English speaking students "who may not be confident about their English-language skills can be assisted in solving math and science problems." Verbalizing might include questions such as:

1. What question is asked in the problem?
2. How did you solve the problem?
3. Do you think you have the right answer? Why? Why not?

The main purpose of such questions is to avail the student of the opportunity to communicate orally, in which ever language they can, the processes they use when solving math problems.

Create opportunities for students to reflect on the main points of the lesson. It is important to summarize the all discussions and to highlight the main points of the lesson. Cuevas (1991) is explicit that students "should be encouraged to explain in their own words, oral or written, the main ideas presented in class." Limited- and non-English speaking students should be allowed to use their native language to explain the main ideas of the lesson, either orally or in written form if they so choose. The important point is to allow them the opportunity to explain themselves.

In the area of science, the cultural background of students can be used effectively for instruction. One way of incorporating students' home culture into science lessons is to have students investigate scientific properties of familiar items from their own culture. The idea here is that the more familiar students are with their environment, the easier it is to present new, more complicated material or information. For example, with Hispanic students, a discussion of the Mayan counting system and the development of the concept of zero is very useful.

Conclusion

In conclusion, let me suggest that the importance of math & science instruction in the development of English language skills has not been paid much attention. Indeed, as teacher educators we watch from the sidelines alarmed at the lack of progress in mathematics and science achievement among limited and non-English speaking students. And, we wonder what we should be doing differently.

While a reasonable amount of research has been done in this area, very little appears to have entered mainstream teacher education. Let me suggest that the problem is not the lack of what to do, rather the problem is the lack of response among classroom teachers who do not believe that limited- and non-English speaking children can benefit from content area instruction such as math and science if they don't speak English. It is interesting to note that as we charge into the 21st century with a mandate to reform every aspect of education, including math & science instruction at all levels, there is little, if any, reference made in any reform reports to training teachers to work more effectively with limited- and non-English speaking students. The assumption, of course, is that if we train teachers better, then all children will benefit from their new skills.

This "trickle-down" approach to meeting the needs of limited- and non-English speaking children (Halcón & Reyes, 1991), given the history of previous reform efforts of the past century, is destined to fail because it does not accommodate those most in need of appropriate instruction. Present reform initiatives simply do not address the issue of comprehensible input for limited- and non-English speaking, preferring instead to insist that all instruction be done in English. Given the demographic reality of the Southwest, and the fact that little has been done to train new teachers to teach literacy, mathematics, or science to limited- and non-English speakers, I am not optimistic that present reform efforts will produce the results we all so desperately seek. I trust that by broadening the our scope of our discussions to include the educational needs of these children is a step in the direction of academic success for *all* students.

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SPECIAL ISSUES IN TEACHER PREPARATION

PANEL SESSION 5:

Technology in Science and Mathematics Education

INTEGRATED MEDIA TECHNOLOGY IN MATHEMATICS TEACHER EDUCATION

Elizabeth Goldman
Vanderbilt University

INTERACTIVE VIDEO ACTIVITIES FOR ELEMENTARY EDUCATION STUDENTS

Dean Zollman
Kansas State University

USING HYPERMEDIA TO INVESTIGATE AND CONSTRUCT KNOWLEDGE ABOUT MATHEMATICS TEACHING AND LEARNING

Deborah Loewenberg Ball, Magdalene Lampert, and Mark Leland Rosenberg
Michigan State University

TEACHING STUDENTS MEANINGFUL THINKING STRATEGIES IN BIOLOGY

Kathleen M. Fisher
with J. Faletti, J. Lipson, B. Wyman, & B. Miller
San Diego State University

INTEGRATED MEDIA TECHNOLOGY IN MATHEMATICS TEACHER EDUCATION

Elizabeth Goldman
Peabody College of Vanderbilt University

Introduction

Most university certification programs for prospective elementary school teachers require a course in mathematics methods and materials, which is frequently supplemented with a field placement or practicum. Over the 15 or so years I have taught such a course in Peabody College of Vanderbilt University, I have struggled with the need to integrate what we know about mathematics, about learning, about teaching, and about children and schools into an experience that is both practical and theoretical--a course that will give beginning teachers specific techniques and strategies, as well as the theoretical foundations that allow them to make wise choices about when to use these strategies.

Teacher education has been criticized for failing to prepare teachers to analyze and solve problems in the complex world of the elementary school; many argue that this occurs because the theory we teach in university courses is divorced from its site of application (e.g., Berliner, 1985). In-school observations and field placements are valuable components of teacher education, but the complex, fast-moving elementary school classroom does not provide an environment that encourages reflection and analysis by novice teachers (Copeland, 1989), who often fail to notice or misinterpret critical features of the instruction or learning (Berliner, 1986; Carter, Sabers, Cushing, Pinnegar, & Berliner, 1987). Written vignettes or cases afford a shared context for discussion in teacher education courses (National Council of Teachers of Mathematics, 1991), and they can be annotated to provide links to the literature, but they often obscure the complexity and immediacy of the environment in which teachers must make instructional decisions.

For the past four years, my Vanderbilt colleague Linda Barron and I have been using video to provide a context for the study of teaching and learning mathematics in our elementary and early childhood mathematics methods courses. Because we were not able to find suitable materials when we conceived the project in 1986, we sought and received funding from the National Science Foundation (NSF) to produce our own. From early experiments with edited videotapes, we moved into the production and use of videodiscs and computer software. Both the technology and our understanding of how to use it have changed considerably since we began the project. The purpose of this paper is to describe our experience in producing and using the materials--what we have learned and what we still need to find out.

Theoretical Assumptions Underlying Design and Use of the Materials

Three assumptions about learning to teach elementary school mathematics have guided our selection of video incidents and the way we have incorporated these into the methods courses (Goldman & Barron, 1991):

Assumption 1 - knowledge. There is a body of information that prospective elementary school teachers need if they are to engage in the kind of teaching envisioned in NCTM's Professional Standards for Teaching Mathematics (1991). The literature on anchored instruction (Bransford, Sherwood, Vye, & Rieser, 1986; Cognition and Technology Group at Vanderbilt, 1990) or situated instruction (Brown, Collins, & Duguid, 1989) implies that learning is more effective and transferable if this information is encountered in context.

Assumption 2 - beliefs. The way a teacher teaches mathematics is related to beliefs that he or she holds about what mathematics and mathematics instruction are (Clark & Peterson, 1986; Lampert, 1987). Preservice teachers need to see alternatives to traditional mathematics instruction, and to develop analysis/reflective skills to evaluate the effects of different types of instruction upon mathematics learning.

Assumption 3 - enactment. Novice teachers attempting to conduct whole-class instruction need opportunities to see, analyze, and practice teaching sample lessons. Specific techniques or strategies that experienced teachers use to carry out complex instruction need to be pointed out to the beginning teacher, and the contextual bases upon which expert teachers make planning and interactive decisions need to be made visible.

The purpose of the video that I use in the methods course is not to show preservice teachers how to teach mathematics; in fact, no one of our video lessons is, in its entirety, what I consider a "model lesson." For this reason, some degree of instructor mediation in the use of video illustrations and cases is essential. When I use the video, I usually show fairly short segments, interspersed with comments to provide a context for the illustration or questions to stimulate discussion. This means that I need rapid access to video segments, and it means, also, that the video segments that I use are likely to be meaningless to someone else (or to me a year later) without lecture notes. New developments in videodisc and integrated media technology make it possible to "annotate" video with text or to supplement text with video illustrations. This not only provides a mechanism for recording or preserving the instructor's use of the video, it also has the potential for replacing or changing the instructor's role in the delivery of the information.

Videodisc and Integrated Media Materials

The terms hypermedia, multimedia, and integrated media refer to the non-linear integration of information from a variety of media (text, audio, video, computer graphics) controlled by a computer program. For example, in one of our programs (Barron, Witherspoon, Bassler, Goldman, & Williams, 1989), an outline of text on a computer screen lists several common misconceptions in children's understanding of fractions. By moving an electronic pointer around on the screen and "clicking" the mouse on various words or icons (pictures), I can show examples (from a videodisc) of children drawing pictures to represent fractions, show a videodisc segment of a teacher dealing with one of the misconceptions, or access relevant bibliographic citations (see Goldman, Barron, & Witherspoon, 1991, for a more complete description of these materials and their use in the methods course). These electronic links allow me, as instructor, random and immediate access to a wealth of information and video illustrations. The computer program that we use to provide these links is written using HyperCard, an authoring tool available on Apple Macintosh computers.

Delivery of the video through a videodisc offers two main advantages over videotape: rapid random access to any one of 54,000 frames of video on the disc, and the ability to access selected segments of video with a computer program (essential, if the video is to be used in an integrated media format). The disadvantages are several: one side of a videodisc can contain a maximum of 30 minutes of running video; videodisc players, while not significantly more expensive than a good VCR, are not as widely available; we cannot press videodiscs in-house or make multiple copies once a disc has been pressed; and the pressing of a scratch (single copy) videodisc from an edited videotape costs $200-400.

Questions Raised/Lessons Learned

As we have developed and worked with the materials, we have been faced with decisions and tough questions. The issues that we have been confronting are especially challenging because they are highly interdependent and difficult to isolate. For example, decisions about the design of the materials depend not only upon course goals and theoretical perspective adopted by the instructor, but also upon whether the materials are to be used primarily by students or primarily by the course instructor, and this choice depends upon--and influences--the choice of technology to use.

Who has control? Our first HyperCard programs were intended to be used in a presentation format with both computer screen and video displayed (from separate sources) to the class. When used in this way, text in a HyperCard program can serve as both lecture outline and overhead transparency. The ability to pre-select incidents and to start and stop the video with a controller built into the program allows the methods course instructor to show and analyze elementary school mathematics instruction much as a color commentator can provide "instant replays" and "expert commentary" in a televised athletic event. This ability to stop the action simplifies what is, to a novice teacher, a highly complex and confusing system of interactions among teacher and students.

Gradually, our electronic lecture outlines became more elaborate as we built in links to literature, incorporated questions or comments about lessons or incidents, and included ancillary information such as lesson plans or student products. We stored the HyperCard programs on machines in the computer lab and invited students to browse in the programs to review lectures, print notes, or obtain additional information--and we began to hold some of the methods classes in the computer lab where students had individual access to the programs during class. However, the student machines could not access the video (since there was only the single disc and videodisc player connected to the instructor's presentation system). A number of the students were quite enthusiastic about getting their hands on the computers, but some preferred to watch the instructor's computer screen display, feeling that working the computer was not worth the effort if they could not control the video as well (Goldman & Barron, 1990).

There are a number of practical and pedagogical reasons why we would like the students to have independent access to the materials both in and out of class. For instance, we often use small-group discussions and activities in the methods class, and we may want the groups to study and discuss a series of video incidents. If the groups must wait for the instructor to show the incidents, it means that they cannot explore, revisit, and discuss at their own pace. Also, we have accumulated more information and video-based activities than we can use in the hours available for the methods class, and we would like for this information to be available to students. The move from materials that are primarily instructor resources to ones that are to be used by students raises a new set of issues.

What level technology do we choose? It is expensive to provide individual video workstations. At present, we must use separate videodisc players and videodiscs for each student station if students are to have individual access to a full integrated media system (although digitized video and larger-capacity storage will likely solve this problem in the near future). It works well to have a group of four students at each station, and five per station is possible. We use five stations for in-class activities, and we must have five separate copies of a videodisc (if each station is to be accessing video from the same disc). These arrangements will be obsolete when the technology advances to the point that it is economically possible to store and manipulate large amounts of digitized video, but we made the decision to approximate this "lab of the future" in order to be able to test prototype integrated media products for independent student use.

One advantage of HyperCard as an authoring tool is that programs can be created to run on low-end Macintosh equipment (our student machines are SE models with hard drives that have RAM upgraded to four megabytes). We have made decisions not to use some of the newer features of HyperCard, such as single-screen presentation, because we want to be able to run the programs on the machines we now have in the lab.

Is it possible to design a single system/program that incorporates all of the information and activities, in such a way that it is intuitive and easy for students to use independently? Because integrated media systems access information in a non-linear fashion, the user is freed from the sequential organization of linear text and able to move through the information along a variety of paths. But if there is a large body of interconnected information, users may become lost in the system or distracted from the original learning goal by the multiple opportunities for exploration (Marchionini, 1988). Some designers are using a map or other graphic to provide an "external representation of the overall structure of places to go in the system, while marking the user's current place" (Hasselbring, Goin, & Bransford, 1991, p. 29).

We have begun to work on a design idea that we are calling the "professional development school metaphor" in which a floor plan for a hypothetical professional development school provides a representation of the information and tools that are (or will be) located in the system. For example, in the "demonstration classroom", prospective teachers can access 10-15 minute edited versions of sample lessons taught by experienced teachers. A "notebook" feature with video controller allows the viewer to stop the lesson and enter comments. Since the viewer has logged onto the system, the course instructor can retrieve the "notebooks" of the students who have analyzed the lesson. A file cabinet in the demonstration classroom contains additional resources for each lesson, including written lesson plans, pupil materials such as tests or practice sheets, and information about the mathematics involved. The "computer lab" contains a file cabinet which accesses a data base of mathematics software. In the "conference room" preservice teachers can review the demonstration lessons and access comments by participants in the lesson (teacher and student interview data which we have collected for several of the sample lessons) or comments by the methods course instructor or other university personnel. Some of the components of the system are operational and are being tested in the methods courses this year.

What level technical expertise is required? The degree of technical expertise necessary for an instructor to use HyperCard programs that someone else has prepared is different, obviously, from that required to design and create the programs. If one is familiar with Macintosh equipment, it is a fairly simple matter to learn how to connect a videodisc player and get into a HyperCard program. Most institutions have individuals on campus who can provide information and technical support to an instructor wishing to use a pre-existing program or to create a simple lecture outline program with "buttons" to access video segments from a videodisc. Because we have development funding, we are able to hire a staff member to do most of the programming for the materials, but Linda and I have both acquired enough familiarity with the software to be able to create our own HyperCard lecture notes.

We have found that there are enough students in our classes with Macintosh (even HyperCard) experience that little or no computer orientation is necessary when students use the materials independently. We simply poll the class to see who is familiar with the equipment and be sure that there is at least one "expert" at each station. It is the "expert's" responsibility to orient the others in the group. We do have to go through a short introduction to the videodisc player.

Does the use of integrated media materials make a difference in the preparation of elementary school mathematics teachers? We have found evidence that the use of video illustrations in the methods course influences the way student teach mathematics in the field placement Specifically, we found that preservice teachers are more likely to exhibit a teaching practice if they see and analyze video examples than if they are exposed to the practice through course readings or lecture alone (Goldman & Barron, 1990; Goldman, Williams, Bassler, Sherwood, Barron, & Witherspoon, 1990). In other videodisc projects conducted at Vanderbilt, Randolph, Smithey, and Evertson (1991) found that preservice teachers instructed in classroom management concepts using a lecture/discussion format supplemented by videodisc examples and HyperCard text wrote better definitions of concepts and longer narratives of classroom events than did students in a control group instructed with a traditional lecture/discussion format using no hypermedia materials. Risko, Yount, and Towell (1991) used video-based case analysis in a remedial reading methods course and reported preliminary findings that indicate that experimental class students' comments were more rich and elaborative than those of students in the control class.

But what, if anything, does a full integrated media environment add to the benefits obtained from the instructor showing video? If, as the above studies suggest, the use of video for illustration and analysis can improve preservice teachers' understanding of what goes on in the classroom and can influence their own performance, and if we can make this information and these activities more readily available to preservice teachers by locating them in a system that can be used independently, then it seems that the system will be worth the effort. On the other hand, we are not sure if the system is an effective substitute for a course instructor. It is not likely that we can answer these questions until we have functional systems to evaluate.

Who will produce the materials? The first step in the production of integrated media materials is obtaining suitable video, and this has been particularly problematic for us. There are technical issues (you have to be able to hear what the children say), ethical issues (some of our "best" examples are of what not to do), and pedagogical content issues (much of the mathematics instruction that we find in the schools is still rule-based and highly teacher-centered). We have found that we obtain better video examples if we work closely with the teacher (in some cases, our own graduate students) to plan the type of instruction or mathematics topic that we need instead of just taping random lessons. The examples that we use as cases for analysis are real examples that occur spontaneously in real classes, and these are difficult or impossible to set up on demand for videotaping. The technical quality and content of the video that we are now producing is superior to our initial attempts, but still well below studio or commercial quality. I expect that we will not have widespread dissemination of integrated media materials until commercial publishers believe that it is economically feasible to produce the video.

If an instructor has access to classroom video, a 30-minute videotape can be converted to videodisc format for $300 or less. Preparing a master disc with multiple copies is considerably more expensive, with the mastering process costing up to $2000. When a disc is mastered, however, the cost for each copy is usually less than $20.

Conclusion

I am enthusiastic about the use and potential of integrated media materials, but I do not want to convey the impression that all, or even most, of the activities and assignments in the methods course I teach are video-based. We still do such things as group problem solving, student reports, activities with manipulative materials--and I still lecture. The ready availability of the video and other information has changed the way I think about instruction, and there are different demands for class preparation. As with any other new approach, things are easier the second and third time around.

We have only begun to understand possible applications of integrated media technology to teacher education. Faculty at Vanderbilt in other content areas are developing and using similar materials for their courses, and the sharing of approaches and design ideas has been extremely useful to us in our project. Clearly, it is not practical for each of us to produce our own materials "from scratch," but it is likely that some critical number of us will have to produce, share, use, and evaluate prototypes before commercial distributors will be willing to invest in production costs.

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INTERACTIVE VIDEO ACTIVITIES FOR ELEMENTARY EDUCATION STUDENTS

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Young children have a natural interest in science. That interest can be fostered and developed by teachers who are able to respond to the pupils, or it can be stifled by teachers who lack understanding of science and how to teach it. While teachers must have some background in science, they must also be able to select learning experiences which are appropriate to their pupils. Thus, learning science and ways to teach it is an important component of the education for students who are preparing to become elementary school teachers.

To provide a background in science, Kansas State University requires all future elementary school teachers to complete at least three science courses and a course in the teaching of science. Most of these courses present science in a standard lecture-laboratory environment. In one course, Concepts of Physics, we have established a teaching/learning model which provides experiences similar to ones they should use in the elementary classroom. In developing this course we had two important considerations:

- the students should be involved in many hands-on activities which also engaged their minds, and;
- the students must discover direct connections between the physics learned in the classroom and the rest of the world.

Thus, the laboratory is a critical component of the course. However, students have a particularly difficult time making the connection between physics in the laboratory and physics in every day life. To address this problem we integrated multimedia activities into the laboratory.

Multimedia in the Physics Course

This course serves the students who are preparing to teach school at the kindergarten through sixth grade level. Approximately 120 sophomore and junior students enroll in the course each year. The primary purpose of the course is to provide these students with sufficient background in physics so they may teach science at the elementary level. As stated above, an equally important goal is to provide a role model for effective science teaching.

To create an appropriate learning environment, we based the course on the Learning Cycle created by Karplus (1977). This constructivist approach contains two student-centered activities--an exploration and an application--and one teacher-centered activity--a concept introduction--during each cycle. The Learning Cycle is generally used in small enrollment courses. It was adapted to our large enrollment course as explained below (Zollman, 1990).

Explorations begin each cycle. During an exploration, students look at situations and observe phenomena without trying to analyze them in detail. These activities form a basis of common experiences for all of the students in the class. They are used as a starting point for discussions which lead to the introduction of physics concepts. Multimedia activities are included in the explorations. Students observe scenes such as sporting events and car collisions, then answer questions which are related to the concepts to be introduced that week. Students complete this work in an open laboratory on Monday or Tuesday of each week.

Concept Introductions occur in a large class setting on Wednesday. Beginning with the observations of the exploration we develop ideas which can explain them and provide underlying theories for them.

Applications ask the students to apply newly learned concepts to new situations. Many of the application activities involve standard laboratory equipment or toys. Others use multimedia to help the students connect the physical concepts to everyday events. For example, the students see a video of a famous prize fight and are asked to apply momentum conservation to a punch. The questions which they must address is: was the person who fell down really hit? By controlling the video and viewing the scene one frame at a time, the students may draw some conclusions and justify the conclusions based on their knowledge of an important physics concept. Likewise, they analyze situations such as the forces on a diver as she travels from the diving board to the swimming pool, the motion of a mannequin which is restrained by a seat belt during an automobile collision, and the variety of phenomena which led to the dramatic oscillations and collapse of the Tacoma Narrows Bridge. These activities make the connections by forcing the students to apply their newly gained knowledge to real and sometimes complex events.

Table 1 provides a list of multimedia activities for the explorations and applications.

Table I

Explorations and Applications using Interactive Multimedia

Who's Upside Down?
Frames of Reference

Students must determine which of two people is upside down and type reasons for their conclusions into the computer.

A Matter of Relative Motion*
Physics: Cinema Classics

By viewing identical events from three different reference frames students learn from measurement what stays constant and what varies when the reference frame changes.

What's Moving?
Frames of Reference

By using slow motion, students measure speeds in two seemingly identical situations. They are then asked to determine whether it is the person or the background that is moving in each of the scenes.

Did Anyone Get Hit?
Pioneer Demonstration Videodisc

Students view a controversial "punch" in a prize fight between M. Ali and S. Lisbon. They use slow motion to look at the scene closely then use conservation of momentum to discuss whether or not Ali's punch actually hit Lisbon.

Air Bags and Impulse
Physics and Automobile Collisions

Students measure the impact time for mannequins as an automobile strikes a wall. One mannequin collides with the windshield and dashboard, while the other collides with an air bag. Then the students apply their knowledge of impulse to the scene.

No Forces in Space
Skylab Physics

Students explore the motion of astronauts upon whom no external forces are acting.

Backward and Forward in Time
Skylab Physics

Students apply the Second Law of Thermodynamics to determine if a video is played forward or backward.

Seat Belts and Inertia
Physics and Automobile Collisions

Students analyze the motion of a mannequin during an automobile collision. The mannequin is restrained by a seat belt and should strap. They contrast the motion of the mannequin's head with that of its body. Then they apply Newton's laws to describe their observations.

Hammer and Feather on the Moon
Spacedisc 2: Apollo

Students measure the fall of a hammer and a feather that were dropped by an astronaut who was standing on the surface of the moon. Students complete the same experiment on earth and compare their results with the experiment on the moon.

Forces on a Diver
Studies in Motion

Students analyze the forces on a diver from the time she steps onto the diving board until she is submerged in the water.

Vaulting Energy
Physics of Sports

Students apply conservation of energy to a pole vaulter. By collecting data from a video scene they compare the kinetic energy during the athlete's run with his gravitational potential energy at the top of his motion.

Thermal Energy Around a Campfire *Windows on Science, Volume 1*

Students analyze a series of campfire activities and determine how thermal energy is transferred.

Waves and Resonance
The Puzzle of the Tacoma Narrows Bridge

Students study the properties of wave motion and resonance by completing the lesson prepared for this videodisc. Wave motion is not presented at any other time in the course, so this videodisc lesson is the treatment presented.

*This activity is being developed now and will be included next year.

The multimedia activities are not separated from other hands-on activities in the course. Students move quickly and easily from an experiment which involves standard teaching laboratory materials to a multimedia station and back to laboratory apparatus within a single class period. Thus, in addition to providing examples of engaging the students' minds, the integration of activities provides a model for including all types of appropriate activities in the learning experience. No distinction is made between using high technology and low technology. All are simply part of the integrated, student-centered learning experience.

During the teacher-centered concept introduction and summaries at the end of the week, videodisc materials are presented using a large screen projection system. The instructor controls the videodisc using barcodes which are integrated into the class notes. Some examples of these activities are:

- Viewing the effects of acceleration on astronauts in the Space Shuttle.
- Looking at the behavior of toys in space.
- Discussing the difference between velocity and acceleration by viewing a sprinter and distance runner over short intervals.
- Calculating the latent heat of fusion of the Wicked Witch of the West by watching her melt after Dorothy throws water on her and by making approximations based on visual clues.

The interactive video materials have become an integral part of this physics course. They provide students with ways to connect to real-world situations, to "experience" situations which they cannot otherwise experience, and, occasionally, just have fun.

Development of the Multimedia Materials

The physics course for elementary education majors began in approximately its present format in 1977. The multimedia integration was introduced in 1979 with the use of a stand-alone MCA-DiscoVision videodisc player which was controlled by a small keypad. Since that time the course and the multimedia component have continued to evolve. Each year since 1979, new interactive video materials have been added to the activities performed by the students. Each activity is designed over a period of a few weeks and then implemented into the next offering of the course. Revision of materials is a continuing process.

Major implementation changes have occurred when the hardware has changed. In 1981 the stand-alone player was replaced by a set of Apple II+ computers which were connected to consumer-level videodisc players (Pioneer VP-1000). These systems, which involved two video screens and limited computer capabilities, were placed in 1990 by IBM InfoWindow multimedia systems. Each change in the hardware has required about three months to convert the activities to new software and to upgrade the activities so that they take advantage of capabilities of the new hardware.

The multimedia activities are now an integral part of the physics course for elementary education majors. The course, in turn, is a standard offering of the Department. Further, other science and math courses for elementary education students are now being developed and are following the general model of this course. Thus, the project is very well integrated into the University's academic offerings and is being used as a model for further efforts.

Advantages of Multimedia in the Environment

The multimedia components of the course are meeting the goals which were established for it. The quality of learning has improved because the students are able to make better connections between physics in the classroom and the outside world. Because they see an effective and appropriate use of technology, they are able to experience a model which they could emulate in their teaching. Thus, the materials offer an effective way for future elementary school teachers to learn about physics and ways to teach it.

Most of the material which is presented using multimedia could not be presented in an interactive way through any other media or teaching technique short of extensive field experiences which use sophisticated measurement apparatus. The time and equipment for such field experiences is not available, and the apparatus would be far too complex for this audience. Thus, multimedia is the only method by which we could interactively present this material to this group of students.

We have not conducted a formal evaluation of the materials. Thus, we have no data or formal evidence upon which to base the above conclusions. We have, however, interacted with and observed students using these materials for over ten years. Our judgment is that they are meeting the goals which we have established for them.

Perhaps the most important aspect of the multimedia component is its model of development and delivery. When most faculty consider becoming involved in multimedia, they begin by investigating the possibility of creating an interactive videodisc. This process with script writing, story boarding, recording, editing and programming is expensive and time-consuming. Most institutions and faculty do not have the resources for such development. In this project we used videodiscs which were created for other purposes and used software to "repurpose" them to meet our needs. Further, the introduction of multimedia did not require any great change in instruction strategies. It was integrated into an existing course to meet a specific well-identified need. This approach to developing and using interactive technologies results in a small strain on resources and a high impact on student learning and faculty teaching.

Acknowledgments

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USING HYPERMEDIA TO INVESTIGATE AND CONSTRUCT KNOWLEDGE ABOUT MATHEMATICS TEACHING AND LEARNING[1]

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Mathematics and Teaching Through Hypermedia is a three-year NSF-funded project whose purpose is to investigate the potential contributions of hypermedia to teacher education and learning to teach. Our work draws on studies of teacher thinking and teachers' knowledge use in practice as well as on studies of prospective teachers' assumptions about mathematics teaching and learning.[2]

Our purpose is to help teacher education students learn to think in new ways about the nature of the work entailed in teaching elementary school mathematics. By using videos of real-time teaching as a starting point, we seek to represent the complexities involved in the moment-by-moment problems of practice and thereby to influence novices' thinking about teaching and learning. We hope to affect their assumptions about what *they* need to know in order to teach elementary school mathematics. By using a hypermedia system to link multiple kinds of information about teaching and learning mathematics in a third grade and a fifth grade classroom across an entire year, we hope to learn about the potentials of new technologies to support novices' construction of an image of teachers' work that adequately reflects the messiness of practice in the classroom.

Three basic propositions about learning to teach mathematics provide the foundation for our work. One deals with the learners of teaching, one deals with what it is they need to learn, and the third centers on the context of that learning. The first proposition is that teacher education students, like any learners, bring a host of ideas and assumption to the learning situation, and that their ideas and ways of thinking must be central to planning effective programs of teacher education.[3] The second proposition is that prospective teachers need to learn that the practice of teaching is complex, shaped by multiple and conflicting purposes, and composed of a wide range of knowledge, insight, skill, and commitments. The third is that mathematics teaching in the U.S. is in need of improvement. We discuss, briefly, each of these propositions and illustrate their consequences for mathematics teacher preparation.

Proposition 1: Prospective Teachers Already Know a Lot About Teaching: What They Bring Can Both Help and Impede Their Learning to Teach

Prospective teachers, as learners, are distinguished for the extensive exposure they have had to the thing they are to learn. Consider the fact that they come to learning to teach having spent over 14 years in classrooms. They have been watching teachers and have developed ideas about what it takes to teach.[4] They even have learned specific things to do--ways to motivate students, neat activities, techniques for managing behavior. They have formed ideas about students, about the factors that affect learning, and about what it means to be a "good" teacher.

The "apprenticeship of observation" is a term that many have used to refer to the extensive experience that prospective teachers have had with classrooms and teachers prior to entering a school of education. Two consequences of this apprenticeship should be noted. First, as the term connotes, prospective teachers have been watching what teachers *do*, but have not necessarily penetrated the inner world of teaching where teachers analyze and reason, argue with themselves and reflect, make conjectures and choices. Imitation based on observation makes for inappropriate learning of a role that is so inherently about things that are *in*visible: thinking, reasoning, deciding, and caring.

A second consequence of the apprenticeship of observation is that what prospective teachers believe is often limited and likely to preserve traditional approaches to teaching and learning, especially in mathematics. They tend, for example, to see mathematics as a fixed set of rules to be memorized, to see mathematics as separate from reasoning and language, and to think that some people are mathematically-minded while others are best-suited for other pursuits. Like the teachers who taught them, their own understandings of mathematics are often weak and they neither appreciate, enjoy, nor feel confident with mathematics. Their images of good teaching are conventional--the teacher stands at the board and shows students what to do--and they think that what they most need to learn are techniques of teaching. These ideas are problematic, particularly in light of the reforms needed in mathematics education.

Proposition 2: Prospective Teachers Need to Learn that Teaching is Complex and Shaped By Multiple and Conflicting Purposes, That Teaching Involves Managing Dilemmas

The purposes for schooling--and thus, for teaching--are multiple and disputed. In trying to meet the needs of students, teachers constantly confront dilemmas.[5] What should be taught? In what ways? How much should school connect with students' everyday worlds and how much should it transcend those worlds? How should democratic ideals be pursued? How much should schools prepare students for the "real world" and how much should it prepare them to change those realities? How can teachers respect kids' thinking and also help them develop conventional knowledge?[6] Given the complexity of the issues teachers face, from the face-to-face problems of classroom interactions to big issues about aims, no set of principles can completely direct good teaching. Instead, knowing in teaching entails weaving together many different kinds of knowledge and insight. It involves weighing and considering competing notions and commitments, making tough choices, and analyzing and reflecting carefully on the consequences of actions and decisions. These complexities are rarely appreciated by prospective teachers.

Learning to teach mathematics, therefore, demands not only learning particular ideas, practices, and techniques, not only subject matter and knowledge of learners, and not just spending time in a classroom. The fragmented ideas about good teaching that students encounter in their teacher education courses have been notably ineffective in helping beginners know what to do when they face the challenges of real classroom interactions. Learning to manage the complex demands of teaching requires that teachers see teaching as complicated, and that they identify, feel, and examine endemic dilemmas of practice. Learning to teach entails developing ways of looking and listening, ways of interpreting and reasoning, as well as ways of being and doing.

Proposition 3: U.S. Mathematics Education is in Need of Reform

The final proposition that underlies this work is the conviction, widely shared, that mathematics teaching in this country is in serious need of improvement. Numerous documents recite a litany of problems evident in current practice.[7] Mathematics classrooms are dominated by memorization and drill and, in spite of this, U.S. students' performance on even relatively straightforward mathematics tasks is poor.[8] Many students do not learn to use mathematics reasonably in everyday life, to appreciate or enjoy mathematical activity, and many fail to develop sufficient competence to pursue careers that require mathematics.

If mathematics teaching is in need of improvement, then mathematics teacher education must change as well. Prospective teachers need to be prepared to learn to teach differently from the ways in which they were taught. Yet, as a consequence of the apprenticeship of observation, prospective teachers lack images of alternative approaches to teaching mathematics. They have never seen teaching that is in the spirit of the NCTM *Standards*. Even if they did not like the way their teachers taught, they cannot imagine any other ways to approach math and are quite stunned by almost anything that is unconventional--discussion, use of concrete materials, or an emphasis on meaning. In watching such teaching, their assumptions shape what they think they see. They are quite sure of their interpretations, often stated as assertions. Those questions they have are often little more than requests for information, for their approach to learning is not typically one of inquiry.

Prospective Teachers' Ways of Seeing and Thinking about Teaching: One Example

Next we turn to an example which will illuminate why these three propositions about learning to teach mathematics lead us to the idea that hypermedia might have potential as a tool in teacher education. With this example we hope to illustrate what we have learned from our experience as teachers and teacher educators about what prospective teachers "see" when they watch innovative mathematics teaching. The teaching that we have been watching them watch is our own--we have been teaching third and fifth grade ourselves, and it is our teaching which is the focus of our hypermedia explorations. This example helps to highlight what prospective teachers bring to professional studies. We start with a brief four-minute visit to _____'s classroom in which two fifth graders talk about one student's approach to the following problem which the entire class has been working on:

If a car is traveling 40 miles per hour, how far will it travel in $3\frac{1}{2}$ hours?

(1:30:23)[9]

T: Now one of the things that I saw as I was walking around was, something that I'd like to see a lot more of. I gave Ahmed a very special challenge. One member of his group said, "I really don't understand these kinds of problems at all."

And I went over there and I said, "Ahmed, can you help this person explain? Can you explain? Help this person understand?" And he said, "Oh yeah, it's just three times, you know, three times ah --- forty, that's all." I said, "But what if the person doesn't know why you're supposed to times? How could you explain that?" And you know what he did? He said, "I know how I can explain that." And he drew a line in his notebook and he explained it, using that line.

Ahmed, do you think you could come up here and show the whole class what you did?
(Ahmed comes up to the board.)
This is a picture of why you multiply to solve this problem, okay?

Ahmed: I drew a diagram --- *(Draws on the board.)*

And alls I did was put forty miles for each hour, and I kept on adding, forties. *(Writes on the board.)*

T: And, how does that explain how you're supposed to multiply three times forty?

Ahmed: Well, like, every hour, you're going, every hour you're going forty miles and so I just added --- I got three hours and then I added forty three times, and then it gave me a hundred and twenty, then I had to take aw --- I had to divide forty in two, in half and that gave me twenty, so I added twenty cause half and hour is half of, like, an hour.

T: And, did everybody in your group understand what you did there, do you think?

Ahmed: I think.

T: Well, I know I only asked one person to really try and understand what you were working on, because I think your group is just beginning to figure out how to work together, okay? Can somebody else in Ahmed's group explain this drawing?

Eva? Thank you.

Eva: Do you want me to come up there?

T: Yeah

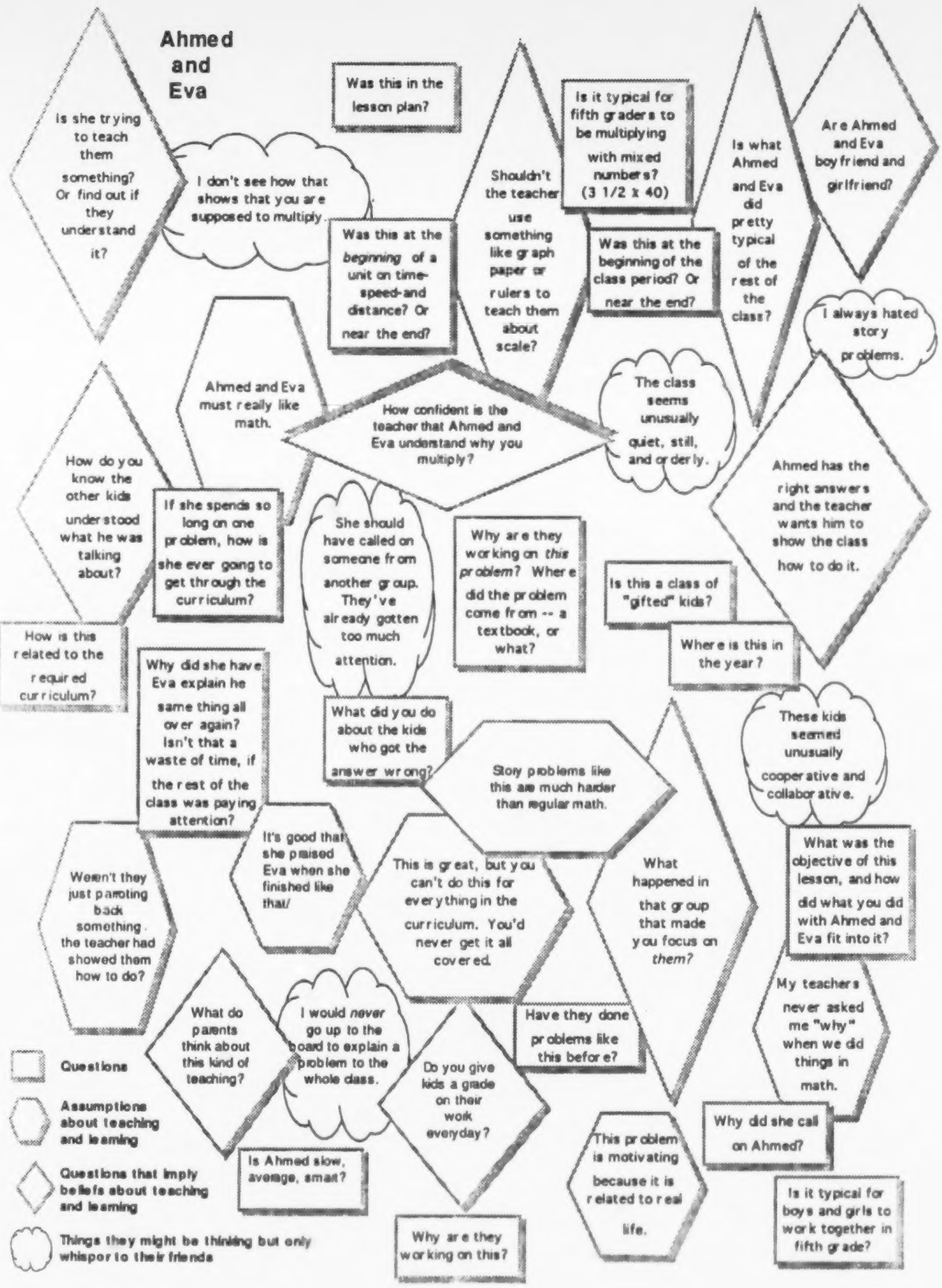
Eva: Arright. It's a good strategy because it says miles per hour and one hour for each one and it's really --- when you get up to one twenty, which is four -- which is three --- four's, you put a half in there because it says three and a half hours, so you put a half right in there. And, um since half of forty is twenty, you add another twenty on and it's one forty.

T: (1:34:30) Good. Very good. Okay.

Next we show a figure that represents preservice teachers' common responses to viewing a segment like this. Their responses show the array of assertions, questions, and feelings that comprise their typical ways of looking at and thinking about teaching and learning. Some of these are the kinds of reactions that would usually only be whispered between teacher education students as they sit together. Others represent the kind of information they want and openly request. Still others represent the kinds of claims they tend to make and assume (See Figure 1).

Three Challenges for Preservice Teacher Education

Three critical challenges for mathematics teacher education emerge from what we have discussed so far. First, teacher education must find effective means of helping teacher education students make breaks with their past experiences with mathematics teaching and learning--and their consequent personal anxiety, thin understandings, notions about the nature of mathematics, assumptions about who can learn mathematics, and ideas about how



Ahmed and Eva

Is she trying to teach them something? Or find out if they understand it?

I don't see how that shows that you are supposed to multiply.

Was this in the lesson plan?

Was this at the *beginning* of a unit on time-speed-and distance? Or near the end?

Shouldn't the teacher use something like graph paper or rulers to teach them about scale?

Is it typical for fifth graders to be multiplying with mixed numbers? (3 1/2 x 40)

Was this at the beginning of the class period? Or near the end?

Is what Ahmed and Eva did pretty typical of the rest of the class?

Are Ahmed and Eva boyfriend and girlfriend?

I always hated story problems.

Ahmed and Eva must really like math.

How confident is the teacher that Ahmed and Eva understand why you multiply?

The class seems unusually quiet, still, and orderly.

How do you know the other kids understood what he was talking about?

If she spends so long on one problem, how is she ever going to get through the curriculum?

She should have called on someone from another group. They've already gotten too much attention.

Why are they working on *this problem*? Where did the problem come from -- a textbook, or what?

Ahmed has the right answers and the teacher wants him to show the class how to do it.

Is this a class of "gifted" kids?

Where is this in the year?

How is this related to the required curriculum?

Why did she have Eva explain he same thing all over again? Isn't that a waste of time, if the rest of the class was paying attention?

What did you do about the kids who got the answer wrong?

Story problems like this are much harder than regular math.

These kids seemed unusually cooperative and collaborative.

Weren't they just parroting back something the teacher had showed them how to do?

It's good that she praised Eva when she finished like that/

This is great, but you can't do this for everything in the curriculum. You'd never get it all covered.

What happened in that group that made you focus on *them?*

What was the objective of this lesson, and how did what you did with Ahmed and Eva fit into it?

What do parents think about this kind of teaching?

I would *never* go up to the board to explain a problem to the whole class.

Do you give kids a grade on their work everyday?

Have they done problems like this before?

My teachers never asked me "why" when we did things in math.

Is Ahmed slow, average, smart?

Why are they working on this?

This problem is motivating because it is related to real life.

Why did she call on Ahmed?

Is it typical for boys and girls to work together in fifth grade?

Questions
Assumptions about teaching and learning
Questions that imply beliefs about teaching and learning
Things they might be thinking but only whisper to their friends

Figure 1
Ahmed and Eva

mathematics is learned.[10] Second, teacher education must help preservice teachers appreciate and manage the complexities of teaching.[11] And third, teacher education must help preservice teachers prepare to construct a kind of mathematics teaching quite different from much of what they experienced as students themselves.

Can Hypermedia Make a Difference in What Beginning Teachers Can Learn?

Our project represents our attempt, as teachers and teacher educators, to address these three challenges faced by teacher education. We want to investigate the design of new kinds of environments for learning about teaching. We want these to be environments which can help prospective teachers learn what it is *like* to teach, rather than learn *how* to teach. We want them to learn to *think and inquire* about teaching, rather than to learn *answers* about teaching.

These aims led us to hypermedia. Hypermedia's capacity to weave together information diverse in nature and rich in context is especially useful for illustrating alternative approaches to teaching and learning and portraying the complexity of practice. Hypermedia environments can provide tools that enable learners to explore teaching and learning in real time, to stop the tape to look at events more closely, as well as to relate real-time events to one another. It can enable teacher educators to assemble materials spontaneously in response to their students' assumptions and questions. Hypermedia is also an excellent medium for facilitating discourse by making it possible for individuals and groups to move within and across perspectives and events, focusing closely on threads at times and appreciating the tapestry at others. [12]

For example, teacher education students looking at the episode with Ahmed and Eva might decide to investigate what came before, seeking to find out what the teacher had done and whether the strategy that Ahmed used had been explicitly taught. They might decide to examine the teacher's journal page from the day to learn more about the teacher's interpretation of the incident. Other students might want to know how competently Ahmed and Eva, as well as their classmates, were able to deal with time/speed/distance problems on the unit quiz. When they see the quiz, new questions and puzzles may be formulated. They may, for example, decide they want to know more about what is expected at this grade level and go off to explore the district's grade level objectives. They may then become curious about how these compare with the NCTM *Curriculum Standards.* Some students may think that Ahmed is gifted, and be interested in exploring his notebook, his test scores, and his contributions to other lessons on other days. Because their own mathematical backgrounds are weak, some students might themselves have questions about the mathematics of time-speed-distance relationships, and their representation in graphical form. These suppositions have guided us in choosing the materials that we believe should be available to users of the sort of hypermedia tools we envision.

A quote from an article by Spiro and Jehng[13] highlights the appropriateness of hypermedia for the kinds of learning and content that we have described:

> The learning of complex content material in ill-structured domains requires *multiple representations*--multiple explanations, multiple analogies, multiple dimensions of analysis . . . . Mental representations need to be open rather than rigid and closed; nonlinear instructional sequences need to be followed to avoid missing key points.

The authors go on to say that this pluralistic approach to learning is crucial for developing "cognitive flexibility": "the ability to adaptively assemble and re-assemble diverse elements of knowledge to fit the particular needs of a given understanding or problem-solving situation." Hypermedia provides the opportunity to construct terrains for investigating teaching that hold promise for helping prospective teachers gain new insights into teaching, transcending their own personal experiences and launching them as creators of practice.

The M.A.T.H. Project

Collecting, cataloging, designing, and piloting comprise four major aspects of our work. Collecting has dominated much of the first year's work (1989-90) and involved gathering video, audio and print records of the mathematics lessons in our two classrooms across the entire school year. In addition to information about what occurred in the lesson, we collected commentaries about what occurred--from our perspectives as the teachers, from the students' perspectives, and from a range of other perspectives. Table 1 provides a synopsis of the material we collected. (An expanded version of this table that includes our rationales is appended.)

Our decisions about what to collect have been based on three kinds of concerns: some technical, some having to do with what we understand about preservice teachers, and some having to do with what we ourselves understand about the practice of teaching. For example, we decided to begin videotaping in both classrooms on the first day of school, end on the last day, and tape most of the lessons throughout the year. Technical considerations here included our desire to make the project a regular part of the classroom environment, rather than an oddity, and our commitment to record ordinary events as they naturally occurred across the year rather than carefully-planned "exemplary" lessons. We also wanted prospective teachers to have access to an entire year's worth of material because we knew that when they observed in our classes they often made erroneous assumptions about what had come before. Our own notions about teaching further supported our decision to tape all year: Curriculum--that is, what is taught and learned--is not easily divided up into "units" or other logical chunks. Ideas, norms, understandings, routines are developed across time, and are revisited and revised at many points throughout the year. A realistic portrait of teaching and learning would need to make possible access to this uneven, rolling, development of curriculum. Some decisions we made about what to collect or how to collect were shaped primarily by technical concerns or resource considerations, others were based centrally on what we knew about the prospective users of the materials and our own thinking about the practice of teaching. For example, we decided to have graduate students in teacher education do the taping. At first we had assumed that the technical quality of the tape would be best if we used camera people with expertise in filmmaking. Within the first three weeks of the project, however, we discovered that "seeing" teaching--and therefore, recording it--depends as centrally on understandings about teaching, learning, and classrooms than on knowledge about video equipment, lighting, and sound. Getting good sound depends as much on knowing where, when, and how to listen to children as on thoughtful microphone set-ups. In the appendix we include a table listing all the material we collected across the school year and our reasons for collecting those particular materials in the ways we did.

Much of our work to date has also centered on developing accessible storage and cataloguing systems for the enormous data base that we have created. We have worked to index, annotate, and store materials in ways that make them accessible physically, conceptually, and electronically as we design beginning examples of the kinds of materials we would like to experiment with. We have been continually engaged in piloting small excerpts from tapes in order

Table 1
Data collected on teaching, learning, and interpretive perspectives across one school year in 3rd and 5th grades

CLASSROOM LESSONS	TEACHER'S POINT OF VIEW	STUDENTS' POINTS OF VIEW	OTHERS' POINTS OF VIEW
videotape of most lessons across the year	daily journal, recording preparation for lessons and reflections on what occurred	photocopies of students' math notebooks	videotaped interviews with observers
audiotape of every class	videotaped interviews after particular classes	photocopies of students' homework	NCTM *Curriculum and Evaluation* and *Teaching Standards*
photographs (slides) of chalkboard during and after lesson	commentary on lesson transcripts	photocopies of students' quizzes	state and district curriculum guidelines
observers' notes for each class period, using a standardized format		standardized tests scores and test booklets	district report cards and commercial standardized tests
transcripts of selected lessons		audiotaped interviews with every student at the beginning of the year	audiotaped commentary and analysis by practicing teachers and teacher education students
		videotaped interviews across the year, during and after class, some small group and some individual	interviews with parents
		video of students in other school contexts	
		videotaped interviews with students during the following school year	

to learn still more about the curiosities and predispositions of teacher education students, information that is crucial to the development of the material.

Conclusion

In the hypermedia environment we are designing, teacher education students will have access to multiple kinds of information--well beyond that to which they would have access in a field experience. We want them to be able to go both more deeply *inside* and more broadly *outside* of teaching. Their initial ways of seeing classroom lessons and hearing children may be challenged by exploring other interpretations and commentaries, by delving more deeply into what students were doing, by immersing themselves in what the teacher thought, noticed, and worried about, and--perhaps--simply through the opportunity to tour and re-tour classroom episodes, on guided tours and through investigations of their own design. We hope that their activities will help them to become aware of their own assumptions and to turn their assertions into conjectures.

The significance of this project is twofold. It has the potential to affect the capacity of novices to appreciate the complexities of teaching and learning mathematics in classrooms. But beyond its use as a tool in teacher education per se, it has the capacity to change the nature of the conversation that researchers and practitioners can have about what goes on in classrooms by making available to scholars and school personnel a much richer set of representations of classroom activity and reflections on that activity, and providing users with computer-supported tools to use those representations to examine their hypotheses and support their assertions. It has the potential to create new ways of talking about and investigating teaching and learning, ways that are more congruent with the messy, complex, and uncertain nature of practice.

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Endnotes

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[2] See, for example: Ball, 1988; 1990b, 1990c; Ball & McDiarmid, 1988; Clark & Peterson, 1986; Lampert, 1985, 1990. Post, Harel, Behr, & Lesh, 1988.

[3] The failure to take prospective teachers' extant assumptions and understandings into account has been proposed as one contributing explanation for the weak impact of preservice teacher education (Ball, 1988b, Holt-Reynolds, 1990, 1991).

[4] The work of Dan Lortie (1975) has been influential in developing this argument. Research on what prospective teachers bring to teacher education has helped to make vivid the outcomes of the apprenticeship of observation, especially with respect to learning to teach mathematics (see, for example: Ball [1988; 1990a, b]; Borko, Brown, Underhill, Eisenhart, Jones, & Agard [1990]; Martin & Harel [1989]; McDiarmid &Wilson, in press; Schram, Wilcox, Lanier, & Lappan [1988]).

[5] See Berlak & Berlak (1981) and Lampert (1985).

[6] See Lampert (1990) for a discussion of connecting students' inventions with mathematical conventions. See also Ball (in press).

[7] See National Council of Teachers of Mathematics (1989, 1991); National Research Council (1989, 1990).

[8] See Dossey, Mullis, Lindquist, & Chambers (1988); Goodlad (1984); Travers & Westbury (1989).

[9] Excerpt from transcript of whole group discussion. Lampert fifth grade class, 11/8/89.

[10] See Ball (1990a) for a discussion of one attempt to do this in a preservice mathematics methods course.

[11] See, for example, Floden & Clark (1988).

[12] What we are trying to create is the opportunity to investigate particulars of teaching and learning while connecting them to the multiplicity of concerns inherent in school teaching. A recent article reporting research on how human beings hear music relates well to what we would like prospective teachers to learn: "A person listening to an orchestra can hear individual instruments while enjoying the overall sound--a feat of discernment that no

electronic listening instrument can come close to duplicating . . . . Most humans . . . hear the blended sound [and] also the violins, trumpets, flutes,and other instruments . . . . [through] a process of 'segregation' and 'integration.'" (Downs, Charles. *MSU News Bulletin*, Feb. 21, 1991) In much the same way, we think, prospective teachers must learn to perceive the wholenesses of teaching--the group, the school, the year, the curriculum--while also learning to discern particulars. Their comprehension of each is dependent on their understanding of the other.

[13] Spiro & Jehng (1990), pp. 168-169.

AUDIOTAPE	to audiotape *all* of the lessons during the year (filed by date)	to generate a complete record of whole group interchanges to make it easier to transcribe lessons		
	to audiotape conversation in a different small group than the one that was being videotaped	to expand the regions of the classroom which were recorded		the teacher is often responding to information of this sort that cannot be recorded using only the video camera
PHOTOGRAPHS (SLIDES)	to photograph the blackboard at the end of each lesson (filed by date)	to ensure that we had records of what was written and drawn on the board by teachers and students; videotape of this is often elusive or of poor quality		
OBSERVERS' NOTES	to have observers write summaries of each lesson describing mathematical content, pedagogical representations, problems that arise from the perspective of the students, activities of five focal students in each class, incidents of potential interest to teacher educators and teacher preparation students, overall agenda	to provide a complex index of lessons		
	to standardize notes and incorporate them into a data base (filed by date)	to make possible searches of various kinds		
	to rotate the preparation of notes among graduate students with different kinds of mathematical background, teaching experience, and teacher education experience	to vary the focus of the notes and avoid a singular focus to give us ideas about what to "see" in the data		it is impossible for any one observer to capture all possible perspectives that can helpfully be brought to bear on instances of teaching
TRANSCRIPTS	to have selected transcripts prepared by clerical workers, later to be enhanced by observers and teachers			"hearing" students is a complex aspect of knowing and not merely a matter of transcription skill
	to standardize transcripts and incorporate them into a data base	to make transcripts of classroom lessons available for searches in the database transcribing all lessons would be too expensive	so that users could, at times, examine transcripts as they view tape	

FROM THE TEACHER'S POINT OF VIEW

DECISIONS ABOUT WHAT TO COLLECT		WHY WE COLLECTED IT		
		Technical Concerns	*Knowledge about Our Audience*	*Understandings About Teaching*
JOURNAL	to keep daily written reflections on lesson preparation and evaluation, including long and short term plans, observations on individual students, design of mathematical problems for each class session, comments on general pedagogical problems		to provide (some) insight into teacher's insights, perspectives, reactions, plans	teacher thinking is a central component of teaching practice
	not to standardize journal entries			teacher thinking and reasoning is complex and does not follow preset categorization schemes
	to type journal entries into a data base (filed by date)	to make it possible to access the teacher journal easily and to do searches for particular students, issues, problems		
VIDEOTAPED INTERVIEWS	to have observers interview teachers on selected occasions before and after lessons	to provide a more vital documentation of the teacher's thinking than is possible in a print medium	to provide an additional window into teacher's insights, perspectives, reactions, plans	teacher thinking is a central component of teaching practice; it cannot be uncovered only through what the teacher happens to write down after a class
	to conduct some teacher interviews in the classroom and include reflections on student work			
	to transcribe teacher interviews and add to data base (filed by date)	to make it possible to access the teacher interviews easily and to do searches for particular students, issues, problems		
COMMENTARY ON TRANSCRIPTS	to have teachers prepare written commentaries on lessons to be linked with specific dialogue and actions that occurred during class		to provide access to more of the teacher's interpretations and ways of thinking, seeing, hearing	teachers "see" and hear differently than other observers of teaching and learning

FROM THE STUDENTS' POINTS OF VIEW

DECISIONS ABOUT WHAT TO COLLECT		WHY WE COLLECTED IT		
		Technical Concerns	*Knowledge about Our Audience*	*Understandings About Teaching*
NOTEBOOKS	to have students use black ink markers to write in their mathematics notebooks	to make copies of students' notebook pages more legible	math notebooks (as opposed to textbooks) will be novel and therefore should be as accessible as possible	
	to photocopy all students' written work, including computational and representational experimentation, conjectures about how to solve the problem of the day, reasoning about conjectures, doodles		makes accessible what students are doing serves to explain how how notebooks function as alternative to conventional textbooks	students differ in their experiences of and interpretations of the curriculum any one problem in these classrooms connected several mathematical topics the notebook as a whole demonstrated the continuity and coherence of each student's experience
	to copy teacher's written comments on students work		makes accessible teacher's assessments of and responses to students' work	figuring out how to interpret and respond to students' work is a complicated endeavor teacher's comments shaped how students perceived and used their notebooks
	to photograph students' written work on occasion	to capture the notebook as a whole and its place in the classroom culture		
	to scan notebook pages into the data base (filed by date and student's name)	to make it possible to link students' notebook pages with other kinds of data		
HOMEWORK	to photocopy all student homework assignments		makes accessible what students are doing serves to explain nature and role of homework in relation to classwork	shows teacher's decisions about what students can profitably do at home
	to scan homework assignments into the data base (filed by date and student's name)	to make it possible to link students' homework with other kinds of data		
AUDIOTAPED INTERVIEWS	to interview all students at the beginning of the year		to show variations in what students bring with them to a math class	students vary widely in the understandings, dispositions that they bring
	to use a standardized interview format that would include personal information, attitudes toward mathematics and mathematics learning, and mathematical content knowledge	to make it easier to compare students and to search database	to show variations in what teachers might try to find out	attitudes and personal information are at least as important as skills testing in understanding what students bring

AUDIOTAPED INTERVIEWS (continued)

	to transcribe all interviews	to make it possible to access, search, cut, and compare interview data	to support the user's capacity to *hear* students	
VIDEOTAPED INTERVIEWS	to have observers interview students on selected occasions before and after lessons	to provide a vivid record of students' reactions to lessons on the spot		how students interpret and what they learn from classroom lessons cannot be determined simply by watching them during class or by looking at their written work
	to conduct some student interviews in the classroom and include reflections on student work			how students interpret and what they learn from classroom lessons cannot be determined simply by interviewing them in a somewhat decontextualized setting
	to videotape selected beginning-of-the year interviews	to make it possible for users to watch students' expressions and be able to compare with in-class behavior and manner		
	to videotape individual and small group interviews with students in the spring following the year of taped lessons		makes available additional material for analyzing students' attitudes, interaction, understandings	
	to interview students during the following school year	to make it possible to follow students for a longer period of time	users often ask what happens to students in the next grade	
WRITTEN ASSESSMENT INSTRUMENTS	to photocopy quizzes and standardized test work across the year		makes available formal student assessment data	
	to give a standardized test at the beginning of the year	to get baseline data on students' understandings that could be used to compare them with other students of the same grade level	to get perspective on how these students compare with other students--i.e., to help dispel the sense that these are unusually "gifted" kids	
MISCELLANEOUS	to videotape lessons with the same students in other subject matter areas		to offer a broader school and social context in which to understand students	
	to photograph and audiotape program at parent-student potluck supper			
	to photograph student self-expressive art projects			
	to videotape students participating in end-of-the-year music and gymnastics program			

FROM OUTSIDERS' POINTS OF VIEW

DECISIONS ABOUT WHAT TO COLLECT		WHY WE COLLECTED IT		
		Technical Concerns	*Knowledge about Our Audience*	*Understandings About Teaching*
VIDEOTAPED INTERVIEWS WITH OBSERVERS ***(mathematicians, sociologists, anthropologists, psychologists, teacher educators)***	to invite outsiders to view tape and to comment on the lessons or interviews observed to invite outsiders to class and to comment on the lessons observed		to help users broaden their perspectives in looking at and interpreting teaching and learning	interpretations and analysis of teaching and learning must be made from a variety of perspectives
NCTM CURRICULUM STANDARDS and TEACHING STANDARDS	to create Hypercard stacks with statements of the NCTM standards about curriculum and teaching	to make it possible to access and create links with the NCTM standards	to help users make connections with and interpret reform statements and visions	
STATE AND SCHOOL DISTRICT CURRICULUM GUIDELINES	to create Hypercard stacks with lists of state and district goals and objectives for mathematics	to make it possible to access and create links with state and district objectives	to help users analyze the language and spirit of curricular requirements as teachers receive them	
DISTRICT REPORT CARDS AND STATE AND COMMERCIAL STANDARDIZED TESTS	to provide examples of report cards required by the school district to provid examples of tests administered to students in mathematics		to help users examine the kinds of benchmarks to which teachers are held responsible	
VIDEOTAPED INTERVIEWS WITH PARENTS	to invite parents to talk alone and in small groups with other parents, reflecting on their own experiences with mathematics and their hopes, wishes for their own children		to make it possible to pursue questions about what parents' reactions are to this teaching	parents' own feelings about mathematics are often anxious; some parents have high expectations for their students' mathematical achievement
AUDIOTAPED COMMENTARY AND ANALYSIS BY PRACTICING TEACHERS AND TEACHER EDUCATION STUDENTS	to include comments by teachers on lessons observed to include comments by teachers on their own views of mathematics teaching		to help users access the opinions and insights of other experienced and beginning teachers	

TEACHING STUDENTS MEANINGFUL THINKING STRATEGIES IN BIOLOGY

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Introduction

This paper reports the first of a series of classroom studies with students in a hands-on biology course for prospective teachers (upper division Liberal Options majors). A major course goal is to change students' habits of the mind, shifting them away from deeply ingrained rote learning styles and toward meaningful, integrated, conceptual learning. The purpose of this study is to determine if there is any evidence that this goal is being achieved. Other course goals include helping students to overcome science anxiety, enjoy biology, acquire confidence in teaching biology, and learn a small number of biology concepts in depth. These goals are accomplished in part through various activity-based biology teaching strategies that we hope students may emulate when they begin teaching.

A Macintosh-based tool, SemNet™, was used to help promote shifts in learning style. SemNet is a general purpose thinking and learning tool with which a user can construct a systematic knowledge representation in the form of a semantic network – that is, a network of concepts linked by named relations, with associated texts and images (Fisher, 1990, 1991; Fisher, K. M., Faletti, J., Patterson. H. A., Thornton, R., Lipson, J., & Spring, C.,1990). The semantic network essentially provides a map of the cognitive terrain that surrounds and gives meaning to a concept. Organizing ideas into a semantic network involves becoming aware of the links between things and it prompts integrative, holistic thinking about a topic.

Students in the course performed and analyzed simple biology experiments and exercises working in groups of four students each. Each student also worked independently with SemNet to summarize and integrate information gained from their laboratory experiments, class discussions, teacher presentations, texts, and other sources.

The first hypothesis tested is that students in this class will shift in their style of thinking toward more meaningful, elaborative, deep processing styles. One method of measuring these changes is with a self-report Inventory of

Learning Processes developed by Schmeck, Ribich, and Ramanaiah (1977). Schmeck and Ribich (1978) validated the Inventory of Learning Processes by comparing its subscales to a variety of other measures including the Critical Thinking Appraisal and the California Psychological Inventory. They concluded that the four subscales measured Synthesis-Analysis, Elaborative Processing, Study Methods, and Fact Retention (Table 1).

The second conjecture to be explored in this study is that students who use SemNet to construct their knowledge about a topic will, as a result of the knowledge elaboration prompted by the software, be prepared to write an extemporaneous paper about the topic from memory. In addition to testing these two hypotheses, various data were collected to give us a better picture of the students in the class.

Materials & Methods

The study involves 56 students in two course sections of Natural Science 412C, Process and Inquiry in the Life Sciences. The following survey instruments were administered before and after instruction: pre- and posttest of biology knowledge, Schmeck's Inventory of Learning Processes (Schmeck, Ribich, & Ramanaiah, 1977; Schmeck & Ribich, 1978), computer and biology anxiety scales (adapted from Fraser, Nash & Fisher, 1983; Docking & Thornton, 1984), an attitude survey, and a demographic survey. Students also completed the Meyers-Briggs personality survey and ten weekly journals.

Students in this class worked collaboratively in groups of three or four. The course is largely investigative (hands-on, minds-engaged), interspersed with discussions and mini-lectures. Each class meets for nearly five hours per week.

Student assignments included constructing three semantic networks to summarize biology learning. Two out of three midterms and the final exam also included tasks involving generation of semantic networks. Many students printed out a semantic network and pasted it up into a large concept map as an extra credit project.

The second hypothesis (that students will write clearly about a topic once they've constructed a semantic network to describe it) was tested on the final exam. Students were presented with a condensed *Scientific American* article, 'Frozen and Alive' by Storey & Storey (1990), and asked to represent its content in a semantic network. When students completed this task, they

Table 1

Schmeck's Inventory of Learning Processes

Scale	Description
Synthesis-Analysis (deep)	high score reflects critical thinking ability, synthetic/analytical organizational processes, and achievement motivation; person tends to be curious, efficient, mature, organized, stable, low on anxiety, effective in dealing with semantic organization or structure; concerned with meanings and implications of words
Elaborative Processing	high score reflects active elaborative approaches to encoding; relates positively to imagery ability; assesses the extent to which an individual encodes information
Study Methods	high score reflects repetitive, conventional study methods; positively related to curiosity but negatively related to critical thinking ability
Fact Retention	high score indicates propensity to retain detailed factual information; positively related to conforming achievement behaviors.

turned in the article, their notes, and their semantic network. They were then asked to write a short essay, from memory, summarizing the article. The articles were scored independently by the instructor (Fisher) and a reading specialist (Wyman).

Results

We attempted to use Docking's Anxiety Survey (Fraser, Nash & Fisher, 1983; Docking & Thornton, 1984) to measure students' anxiety levels with respect to the computer and to biology. To do so, two different forms of the instrument were prepared, one asking about their feelings about the computer and the other about their feelings about biology. The results suggested that this is not an appropriate modification of Docking's scale. Anxiety (or lack of it) appears to be a general state of mind and its causes are not always readily partitioned out. Furthermore, student anxiety levels peak before assignment due dates and drop dramatically afterwards, swamping any possible changes that may occur in their general feelings about biology and/or computers over the course of the semester. More recent data from student interviews suggests that while many Liberal Options students have serious fears about working with the computer at the beginning, they find SemNet to be so much fun that their fears quickly subside.

Students entering NS 412C are largely computer-naive and weak in biology knowledge (in spite of having taken at least two previous biology courses). They appeared to require considerably more instruction about basic computer skills than had been anticipated. As the result of this initial trial run, curriculum materials have been developed to help students acquire many of the computer, knowledge representation, and critical thinking skills they need. These materials were not in place during the study reported here.

The demographic characteristics of students in two sections of NS 412C during spring semester 1991 can be summarized as follows. These sections are fairly typical of NS 412 students in general. The students were 89% female and 25% minority, including Black, Asian and Hispanic. Most students were employed, with about half working 15 hours per week or more.

Ninety percent of the students had taken a high school course in biology and an even greater proportion completed college biology (Table 2). Most students earned B's and C's in these courses. In spite of this academic background, students' average scores on a simple pretest of biology

Table 2
Previous Performance in Biology

	High School Course		College Course	
Course Grade	#Students	Approx. % Students	# Students	Approx. % Students
A	6	10.9	5	9.0
B	24	43.6	19	34.5
C	19	34.5	24	43.6
D, F	-		4	7.0
Didn't Take	6	9.0	3	5.0
Total	55		55	

Table 3
Meyers-Briggs Personality Types Among NS 412C Students

Personality Type	Frequency NS 412C*	Frequency Population+
ESFJ	19.6	13.0
ESTJ	16.1	13.0
ISTJ	8.9	6.0
ENFJ	7.1	5.0
ENFP	7.1	5.0
ISFJ	5.4	6.0
ENTJ	1.8	5.0
ENTP	1.8	5.0
INFJ	1.8	1.0
INTJ	1.8	1.0
INFP	0.0	1.0
INTP	0.0	1.0

* 56 cases observed in NS 412C

+ According to Keirsey & Bates, 1984

knowledge were low -- 36.71 out of 64 possible points, or 58%. This low level of students' biology knowledge is one line of evidence that they have engaged almost entirely in rote learning in these courses, forgetting almost everything they assimilated in a superficial way except for basic word recognition and a stray connection here and there. As one student (in another semester) described her study method:

> I write maybe three or four questions on each note card on the front and then the answers on the back and just by going through those maybe twice or three times I 've memorized everything. I . . I just . . thats just the way that's the best thing for me. Well, you know, its not always good because I cram for tests so . . uh . . and after I've pushed all this knowledge in my brain, after the test I , I , I let a lot of it go out and its by the end of the semester, after finals, I'm almost rebelling by trying to forget everything I've learned. (Gorodetsky, Wyman, & Fisher, 1992)

The Meyers-Briggs scale assesses personality types (Keirsey & Bates, 1984). Certain personality types have been found to cluster in particular professions. We were interested to know if the distribution of personality types in NS 412C differs from that of the general population, and if so, how this might influence our instruction. We found slightly more sensing, extroverted, and judging personality types among Liberal Options majors in NS 412C than among the general population (Table 3).

Does this distribution of personality types among prospective teachers account in part for their frequently negative reactions to science? It is hard to say. Knowing about personality types of students does not tell us very clearly how to alter instruction, but it did sensitize the instructor with respect to her INTP personality and the contrasting modalities of the students.

Students made significant gains in biology knowledge during the semester. These gains can be seen by comparing student scores on a pretest with their scores on a non-identical posttest, as well as by a comparison of 64 identical multiple-choice items that were included in both tests (Table 4). Total possible scores were 64 points for the 64 multiple choice items and 100 points for the entire test.

Perhaps a more interesting finding is that, as predicted, students increased significantly on the deep processing and elaborative processing scales of Schmeck's Inventory of Learning Processes but not on the methodical study or

Table 4
PreTest - Posttest Gains of NS 412C Students

Instrument	Gain	SD
Pre-Test - Posttest	24.89	8.73 ***
Identical Questions	12.46	6.00 ***

*** $p < 0.001$

Table 5
Shifts in Learning Processes of NS 412C Students

	Difference	SD
Elaborative Processing	+.887	0.72 **
Deep Processing	+.736	1.97 **
Fact Retention	-.226	1.65
Methodical Study	-.264	3.04

** $p < 0.01$

fact retention scales (Table 5). Subsequent evaluations of other classes suggests that this may be attributed to the hands-on nature and conceptual framework of the class as well as to use of SemNet, but much more work is needed to make any clear causal connections.

Since Schmeck's Inventory is a self-report scale, and since it is possible that student attitudes toward learning changed (resulting in significant shifts on Schmeck's scales) but that their actual thinking patterns did not, we wanted to look for evidence of elaborative or deep thinking.

For this reason students were presented on the final exam with a condensed *Scientific American* article (Storey & Storey, 1990) as described above and asked to represent it in a semantic network. When they were done, all notes, papers, and nets were collected, and students were asked to summarize the paper from memory. Their summaries were graded independently by a biologist (the author) and a reading specialist with knowledge of biology, with about 79% initial agreement. Differences were resolved by discussion. Considering that most of these students had never read a scientific article before, and that the article was technical and molecular in nature, the students' summaries were judged to be impressively coherent and complete, suggesting that the students were actually assimilating the information in the article in an organized fashion. These are preliminary results. We have not yet collected any comparison data that would allow us to conclude that student skills in reading a scientific article had actually improved or, if it did, that it was caused by any particular instructional treatment.

Reading student journals suggests that few classes taken by Liberal Option students require conceptual understanding and that students find, in general, rote memorization is the study technique with the highest payoff (these data will be analyzed in greater detail elsewhere).

Our students generally found the SemNet exercises to be valuable. Many students with poor learning skills appeared to make significant progress in improving their knowledge organization skills as well as in learning biology, and some were genuinely excited by their insights, as reflected in their journals and in individual discussions.

Discussion

We describe a hands-on minds-engaged biology course for prospective elementary school teachers that emphasizes conceptual learning and uses the SemNet™ software to help students organize their biology knowledge. Students enrolled in the course made significant gains during a single semester on the deep processing and elaborative processing scales of Schmeck's Inventory of Learning Styles. It is not possible to attribute causation to any single feature of the course.

Promoting conceptual learning is not an easy task. It requires, first and foremost, a reexamination of our own beliefs about what kinds of learning we should be promoting in the classroom. It also demands significant alterations in common testing practices. We believe the use of computer-based thinking tools can facilitate students' transitions from rote to meaningful learning strategies.

Liberal Options students are very conscientious; they aim to please and they strive for excellence. They wouldn't use rote memorization if it wasn't successful for them. The blame for rampant shallow learning must be placed largely on an educational system which does not expect or require deep understanding, not on the students themselves.

The consequences of our having created an educational system that promotes and rewards rote learning (all rhetoric to the contrary) are of at least two types. The first is the incredibly low long-term knowledge payoff derived from a tremendous overall effort invested in studying 'for the test'. The second (and perhaps even greater) loss is the students' vision of what constitutes learning and how it is promoted. These students, for the most part, believe that learning and memorization are synonymous. It is this (crippled) vision that guides these individuals as they become teachers. These students didn't create the system, but without strong intervention they will certainly perpetuate it. They will be shaping our coming generations of children for decades, and, from the perspective of the first author at least, we desperately need to do a better job of shaping their worldviews.

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My co-authors have contributed much of the work in this project but not all have had an opportunity to review this manuscript -- thus the first author assumes full responsibility for the summary of results provided here.

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INSTITUTIONAL COORDINATION ISSUES

PANEL SESSION 6:
School and University Collaboration

SCHOOL/UNIVERSITY COLLABORATION

Jack Wilkinson
University of Northern Iowa

THE DEVELOPMENT OF SCHOOL AND UNIVERSITY COLLABORATION IN THE SCIENCE EDUCATION COMPONENT OF PRESERVICE ELEMENTARY MAJOR

Patricia A. McClurg
University of Wyoming

MENTORING: A MENTOR'S PERSPECTIVE

Bj Stone
University of Northern Colorado

SCHOOL/UNIVERSITY COLLABORATION

Gail Shroyer and Nancy Thompson
Kansas State University

INSTITUTIONAL COORDINATION ISSUES

Karen Stucky
Indiana University

SCHOOL/UNIVERSITY COLLABORATION

Jack Wilkinson
University of Northern Iowa

As we move into the 1990's and the 21st century it is more critical than ever that the universities and school districts form collaborative alliances. This alliance should be developed in order to provide direction and experience to both the preservice programs at the universities as well as to the inservice programs in the school districts.

The mathematics education and science education program at the University of Northern Iowa (UNI) has made initial strides to establish a collaborative environment with Iowa school districts. These efforts have lead to the programs described in the following paragraphs.

The Practitioner Committee consisting of four area classroom teachers and one principal have provided direction for and reactions to the content and methods used in our program. This has taken the form of reacting to and reshaping our plans for developing the courses as well as reading and reacting to the course materials once they are in a draft format. By providing travel expense and substitute teacher pay we have been able to glean many practical ideas from the Practitioner Committee.

The linkage to the student teaching experience clearly calls for school/university collaboration. In the program at UNI, the staff have visited each of the ten student teaching centers which provide the field-based student teaching experience. The purpose of meeting with the administrative staff in the respective school districts was to encourage building principals to recommend their very best teachers as cooperating teachers. The principal recommended teachers to the UNI site coordinator for that particular student teaching center and the site coordinator made the recommendation to the mathematics/science team. The teachers who have been recommended participate in a series of meetings with the UNI mathematics/science team. The purpose of these meetings is to:

1) provide them with the opportunity to share their program with one another and with the university staff; and
2) provide us with the opportunity to share what we do in our program so that they will know about the concepts which we develop in our classes.

The staff will also visit each center each year in order to better coordinate the university/school student teaching program. We also invite student teachers and cooperating teachers to come to the UNI campus for one meeting per year. It is a late afternoon/evening meeting with dinner provided. Discussion provides us with feedback on our program and with ideas for improving our program.

The cooperating teachers are encouraged to attend specific meetings which are held in conjunction with our Annual UNI Fall Mathematics Conference and our Annual UNI Science Teaching Conference. This informal setting provides further opportunity for collaborative efforts.

The induction year program has consisted of two-day workshops for teachers who have agreed to work with first year teachers in their respective buildings. These workshops have been conducted by the Curriculum and Instruction staff at UNI. The pilot program in mathematics and science should serve as a model for the university and/or school districts to provide this needed inservice for first year teachers. Teachers were placed in mentor/mentee relationships with beginning teachers. The ongoing, year-long nature of this relationship proved to be very beneficial to the beginning teacher as well as to the mentor.

The undergraduate student organization of mathematics/science minors is called Teaching Educators About Mathematics (TEAM). The TEAM group has a materials sale each semester and invites area teachers to come and purchase inexpensive, handmade manipulatives for their school classroom. This has been a good project for TEAM and provides a good, although small in scope, way to get preservice and inservice teachers together.

The three components of an undergraduate program all have potential for significant collaboration between preservice and inservice teachers. In the first phase, the undergraduate experience needs the "test" of fair validity which classroom teachers can provide. The second phase, student teaching, calls for advanced work with cooperating teachers in order to maximize the effectiveness of the preservice program. Phase three, the beginning years of teaching, provide an excellent opportunity for the "teaching profession" to take on a critical part of the inservice effort, that of helping beginning teachers become excellent teachers. All three of the above efforts are generalizable to preservice and inservice programs in schools and universities. In districts where external funds are needed to support such activities, the Eisenhower program is well suited to fund these efforts.

THE DEVELOPMENT OF SCHOOL AND UNIVERSITY COLLABORATION IN THE SCIENCE EDUCATION COMPONENT OF PRESERVICE ELEMENTARY MAJORS AT THE UNIVERSITY OF WYOMING

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University of Wyoming

Rationale and Objectives

The major goal of our project is to restructure the preservice preparation of elementary education majors so that we are able to produce elementary teachers who can and who will effectively teach science in elementary schools. We knew from the outset that we could not realize this goal without a partnership with classroom teachers in the state. Common knowledge holds that most people teach the way they were taught. The teaching strategies we have targeted are complex, are significantly different from those employed by most teachers (Goodlad, 1983) and require arduous training and practice (Joyce & Showers, 1988; Johnson, Johnson, Holubec & Roy, 1984; Fullan & Pomfret, 1977). Specific feedback during the planning and implementation of lessons in classroom settings greatly enhances the effectiveness of the training (Joyce & Showers, 1988). Exemplary classroom teachers can be models and can coach preservice students in a context that is not available in the University setting.

Interviews and discussions with past students in our program revealed that during their practica and student teaching they were often placed with teachers who did not teach science in their elementary classrooms; or, who treated science as another reading class. Several students indicated that they were told by their supervising teacher that the "hands-on" strategies advocated by their methods instructors were idealistic and would not work in a real world setting. Given what is known about the powerful role played by school culture in the inculcation of new teachers (Joyce, 1990), we realized that we must work with classroom teachers to achieve the desired long term results for the majority of our preservice teachers.

We chose to use the term "Mentor teachers" for the classroom teachers working closely with our experimental program. This terminology will be used for the remainder of this paper. We targeted three major objectives for the work with classroom teachers.

(1) Restructure the science education of preservice elementary majors so that Mentor teachers would become true partners in the education process.
(2) Identify exemplary teachers who would be willing to join us in this endeavor.
(3) Structure activities which would allow the University/School partnership to develop.

Approaches

The first step we took was to determine what aspects of our program could best be achieved by classroom teachers. Research results referenced above and input from exemplary elementary teachers helped guide these deliberations. The following list briefly summarizes the critical elements of our program provided by classroom teachers. Mentor teachers:

(1) Model targeted teaching strategies and techniques in their elementary classrooms for preservice students.
(2) Conduct debriefing sessions with preservice students after the lesson is completed.
(3) Provide opportunities for preservice students to interview elementary children regarding their current understanding of selected science concepts.
(4) Coach preservice student during lesson and unit development and implementation.
(5) Structure opportunities for preservice students to join and participate in coaching teams.
(6) Meet with partners at the University to discuss revisions to all program components.

Our next step was to identify and select additional exemplary teachers who would be willing to serve as Mentors in our project. The first selection process occurred among teachers in the local school district and worked primarily on the basis of self-nomination. A more formal procedure was adopted for the second summer when out-of-state teachers were included. These steps were as follows:

(1) Distribute a description of the program to every elementary school in the state. In addition to detailing the anticipated responsibilities listed above the letter itemized the available support for teachers to attend the two week summer workshop. Support included travel reim-

bursement, a tuition waiver, thirty-seven dollars a day living expenses and a stipend of sixty dollars per day during the summer workshop.

(2) Interested teachers completed the teacher application form which included questions regarding their philosophy of teaching elementary school science and the level of support they had available to them (including materials and supplies).

(3) Several commitments were required in order for a teacher to be considered as a Mentor. They each had to have a coaching partner in the same school building who was also applying as a Mentor and a letter of commitment from their building administrator. This letter had to include commitment to provide a common planning time, time for observation of peer lessons, time for debriefing sessions and a budget for necessary materials. Finally, both the teachers and the building administrator had to agree to attend the two day orientation meeting held at the University during the spring semester prior to the summer Mentor teaching session.

Over sixty teachers applied for the twenty available slots. These applications were screened on the basis of their responses to the questions and the locations of the school districts. (Since Wyoming is a large state we were interested in schools which could be visited in a two to three day circuit.)

The two day orientation meeting was the third formal activity. Administrators and teachers participated in activities which acquainted them with the philosophy of the program, the program components, and the University personnel involved in the project. The teachers were able to meet each other, share their interests in science education and contribute suggestions to the individuals developing the content and seminar experiences.

The two week sessions held in the summer were the most intense times for interaction among program personnel. During this period teachers were introduced to three major topics - coaching, a modified learning cycle, and cooperative learning. For each of these topics teachers were provided with an overview of research findings including what has been learned about students' misconceptions, strategies for determining students' conceptions, and essential elements of instruction which can help students confront and process these conceptions. Selected readings addressing each of these areas were distributed and discussed. Outside consultants in the areas of cooperative learning and coaching conducted one day sessions with the Mentor teachers and the University science education faculty. Project staff and Mentor teachers modeled the learning cycle and cooperative learning several times during the two week period. Opportunities to practice implementing the strategies and to practice coaching were provided with peers and with elementary school children. The teachers then applied this knowledge in the development and subsequent implementation of a unit plan.

During the following academic year Mentors coached their partner on the teaching strategies. A graduate assistant traveled to each site three times to discuss progress, needs and concerns as well as to provide additional modeling or coaching. The dialogue which was started during these activities has been maintained via yearly Mentor teacher meetings held at the University. Teachers' travel, lodging, food and substitute salaries are provided by the grant. In addition to these grant sponsored meetings the Mentor teachers themselves have organized "get togethers" at Wyoming's State Interdisciplinary Conference. Additional communication has occurred through newsletters, telephone calls, and one conference call.

Outcomes

Formative evaluation results from the School and University collaboration component of our project have been positive. The processes set in place for collaboration have resulted in numerous suggestions for substantive changes in our program. Teachers' comments following the summer workshops were extremely supportive. The yearly meetings have been helpful. Teachers have been quite perceptive in identifying strengths and weaknesses of the program and have contributed creative suggestions for improvement.

Preservice students consistently place high value on their interactions with Mentor teachers. Observing Mentor teachers teaching effective science lessons and seeing firsthand the children's excitement has had a tremendous impact on our students' motivation to teach science. The opportunity to interview children about their understanding of a science concept has caused the preservice students to reflect on ways to modify their teaching. Students rate the debriefing sessions and the coaching sessions following practicum teaching experiences as valuable for improvement of their own teaching.

We received the following comment from a Mentor teacher who was supervising one of the pilot preservice students:

> I've supervised several student teachers before but this was different. From the start we had shared vocabulary and experiences. I didn't have to review or explain what learning cycles or cooperative learning were all about. To make her feel comfortable we both coached my partner first - starting with planning, observing and debriefing. She had participated in coaching before and she quickly became a member of our team. We learned from her; she learned from us. (Mentor teacher, 1990-1991 school year)

While the summative evaluation of the impact of our program must wait at least two or three more years when our graduates will have classrooms of their own, preliminary results indicate we are progressing in the desired direction.

An unanticipated outcome of the Mentor component has been the extensive networking among the Mentors. They have visited each others school districts and shared ideas for getting grants as well as the most recent elementary science project activities occurring in their districts. Several Mentors have adopted science activities such as parents' science night and science clubs that they learned about from other Mentors.

Recommendations

We have learned that for a model such as ours to work the administrators in the classroom district must be involved. Including them in orientation sessions and follow up sessions is imperative. Administrative commitment for the project needs to be obtained up front so that activities which put additional time constraints on already busy individuals (such as team planning and coaching) can occur.

We misjudged the expected time line for preservice students to reach the student teaching phase of our program. As a result we have had Mentor teachers who have had to wait two years before receiving one of our students. While Mentors have been very understanding we would recommend trying to avoid such a time lag.

We believe true School and University collaboration is essential if we are to truly affect preservice education. We highly recommend that Institutions of Higher Education form true partnerships with classroom teachers to work on the improvement of education at all levels.

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MENTORING: A MENTOR'S PERSPECTIVE

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My life changed dramatically in the fall of 1989. It was at this time that I left the comfort and security of South Valley Middle School to become a mentor teacher in the NSF Pre-Service Elementary Mathematics/Science Project at the University of Northern Colorado. Being a mentor teacher has been one of the most challenging and rewarding experiences of my educational career. When I return to a public school classroom, my teaching techniques and strategies will encompass and reflect much of what I have learned through my mentor experience.

The mentor component of the NSF Pre-Service Program has formed a collaborative link between local school districts and the University of Northern Colorado. The program has instituted a win-win-win situation in the fact that the University, the school district, and the mentor teacher each benefit from this innovative experience of collectively sharing resources.

University Perspectives and Benefits

The multiplicity of the University benefits is derived through several means. The professors, who make up the senior staff, are given an opportunity to work with a seasoned classroom teacher who is knowledgeable about and competent in the use of a variety of teaching strategies. The use of cooperative learning, hands-on/minds-on activities, and motivational and questioning techniques are a few examples of the strategies shared by the mentor teachers. The mentor teachers also serve as a sounding board for senior staff as they determine what content would be most appropriate for the pre-service teachers. In addition, mentor teachers provide a reality check about the day-to-day occurrences in an elementary classroom and lend credibility that what is being taught at the University is indeed what will become essential for survival and success in an elementary classroom. Professors relate that through their interaction with mentor teachers, they have become greater risk takers in experimenting with different teaching styles. Their desire to learn more about and practice what is being initiated in the current research on the teaching and learning process has also increased.

Teaching teams consisting of a university professor and one, or sometimes two, mentor teachers creates a new instructional norm. The teaching teams are responsible for the planning and delivery of science and mathematics content. Dovetailed into the science and math content are a variety of pedagogical approaches which are modeled to not only enhance immediate learning, but to be transferred into the practices that will impact future elementary teaching. The teaming concept provides an equally enriching experience for mentor teachers and university professors through the sharing of content knowledge and perspectives on teaching methodologies.

One of the strongest indicators for the success of the teaching teams comes in the formation of partnerships that flourish between mentors and senior staff. The relationship is one built upon mutual respect and acceptance. This equality did not happen over night. Senior staff, as a whole, did not know how to take advantage of mentor expertise at the beginning of the Project in an optimal manner. Mentor teachers were often viewed as glorified student teachers. The experience that served as the catalyst in my mentorship occurred one morning after I taught a lesson on metrics. The look on the professor's face was very similar to a look I received from my son a few years ago when I went into his classroom to teach a lesson on fossils. Later that evening after teaching, I asked my son how he thought I did with his 2nd grade class. He responded by saying, "Mom, you were just like a real teacher." It took senior staff a while to realize that mentors were just like real teachers. After the realization, true partnerships and often strong friendships were formed. Mentor teachers and senior staff are quick to respond positively about the impact of the program on their teaching styles, their perspectives about the educational process, and the amount of information and skills that they have gained from one another. After this tremendous experience, neither mentors nor senior staff members will ever again approach teaching using their old styles.

School District Perspectives and Benefits

The local school districts provide veteran classroom teachers to serve as mentors in the NSF Project. The mentor teachers are relieved of their district teaching duties for a period of one year. A certificated classroom teacher replacement is provided through the University Teacher Induction Partnership program (TIP). The certified teachers in the replacement pool are often first-year teachers or teachers who are returning to the profession after an extended time away from the classroom. The mentor teacher usually spends time with the TIP teacher in order to ensure the continuation of district programs and to enhance the teaching skills of the replacement teacher.

The school districts see direct benefits from the NSF Pre-Service Project in a variety of positive respects. First, many students who are currently in the pre-service program will soon be ready for their student teaching experience, intern programs, and first year teaching positions. These students could serve the district well due to their strong teacher preparation and enthusiasm for the profession. Second, because the local school districts have had the foresight to see the advantages of placing a veteran teacher in a new setting for one year, they receive in return a rejuvenated, recharged teacher, one who has not only increased his/her knowledge and experiential base, but one who is again enthusiastic about teaching. In addition, many mentors after serving in the Project have returned to their respective districts ready to assume more responsibility as teacher leaders; they provide inservice training for building and district teachers and take a larger role in the forward motion of the district. Finally, through the collaborative effort, local school districts are given an opportunity to link directly with a university project that is on the cutting edge of teacher preparation and the educational change process. This change process not only enhances what is and will happen in the district, but also provides the framework for perspectives about future collaborative projects.

Mentor Perspectives and Benefits

It is perhaps easiest for me to sing the praises of the Project from the mentor's perspective. The mentor benefits are only limited by the mentor's imagination and willingness to work. Through $1,500 in professional development money each mentor is given the opportunity to attend local and national conferences, take graduate credit, subscribe to professional journals, gain membership into professional organizations, and pursue academic interests that might not have otherwise been possible. In addition, by establishing a framework to utilize the talents of mentor teachers from several different school districts, the opportunity is created for mentors to network with a broad spectrum of classroom teachers. This network provides for inservice possibilities and the vital sharing of resources, information, and teaching strategies. Through close work with knowledgeable professors, mentors also have the unique opportunity to strengthen and update their science knowledge base in an "on the job" manner.

Due to the fact that mentor teachers are assigned to different courses each semester, they are continually in contact with the pre-service students. This constant interaction lends itself to a positive bonding. Through the bonds that develop between mentors and students true friendships are formed that carry over into other academic areas and into life experiences. Some pre-service students are planning their student teaching experience with one or more of the mentor teachers. The pre-service students often ask mentors to write recommendations, serve as speakers for University organizations, and provide feedback about various course assignments and honors projects. Mentor teachers are sometimes viewed as being slightly more approachable than university professors. Therefore, one of the jobs of the mentor is to facilitate the open communication that is essential between students and professors and enable the bonding process to reach all layers of the Project.

A Look to the Future

The NSF Pre-Service Mathematics/Science Project has positively and eternally touched the lives of all who participated in this unique experience. The win-win-win philosophy pervades all aspects of the program. The three entities, the University, the school districts, and the mentor teachers, have not only come together for the betterment of teacher preparation, but walked away with an enhanced educational philosophy and a renewed faith in the system. The NSF Pre-Service Mathematics/Science Project offers nothing less than a strong action plan for restructuring teacher preparation. Under the leadership of the Project, the mentor model is now being institutionalized into other departments on campus. Hopefully, this innovative approach will soon become the norm instead of the exception.

SCHOOL/UNIVERSITY COLLABORATION

Gail Shroyer[1] and Nancy Thompson[2]
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[2]Manhattan-Ogden School District

Partnerships

A major component of the KSU project is the creation of a partnership between the College of Arts and Sciences, the College of Education, and the Manhattan-Ogden Public Schools. This partnership was realized through the creation of planning teams which include content specialists (scientists and mathematicians), education specialists (science, mathematics, and technology educators, and curriculum and instruction generalists), school system practitioners (teachers and administrators), and students (undergraduates from the first cadre of students). The planning teams are responsible for determining program requirements and developing preservice courses and clinical field experiences. Team members will assist throughout the project with the field testing, revision, and dissemination of the model program.

The project team has been divided into 4 planning teams which are meeting on a monthly basis for collaborative planning seminars. We have a mathematics team, a physical science team, a life science team, and an interdisciplinary team. Each team has several Kansas State University faculty from a science department (Biology, Chemistry, Biochemistry, Geology, or Physics), and/or Mathematics department, the College of Education, several teachers, a building principal, and/or a district administrator, a graduate student, and several undergraduates who began the project fall 1991.

The collaborative planning seminars provide the opportunity for the project team to incorporate the best theories, instructional methods, and materials into the courses and field experiences. The extensive communication and collaboration has resulted and continues to result in a more unified and integrated preparation program.

Through the process of collaborative planning we have developed science and mathematics courses specifically designed for elementary teachers. Instructional methodology courses are being integrated and taught in conjunction with the content courses, and three years of extensive field experiences in school settings will be coordinated with the content and methodology courses.

Professional Development Schools

Three professional development schools have been identified through partnerships with the Manhattan-Ogden Public Schools to function as sites for systematic and long-term clinical field experiences. The three elementary schools, Amanda Arnold, Lee, and Woodrow Wilson, were selected based on past experiences, demonstrated leadership, strong commitment to science, mathematics, and technology projects and curriculum development efforts, and the teacher preparation program at Kansas State University. Each building administrator and the teachers had to demonstrate a commitment to long-term participation as clinical and master teachers. These criteria were jointly created by university and public school project participants. An informational meeting was conducted with all interested building principals who were then requested to submit a written application to the project staff.

Once the three schools were selected, the three building principals were asked to join the project team. These principals, along with district administrators and Kansas State University participants, then developed the criteria for the selection of three clinical instructors and 25 master cooperating teachers. The clinical instructors are considered co-developers of the model preservice preparation program.

Beginning with fall 1991 the clinical instructors have devoted half their time to the project and half their time to classroom teaching. They have taken on leadership roles both within their schools and with project implementation. The clinical instructors are co-teaching the first year courses with the University faculty. The twenty-five (25) master teachers, also involved in planning teams as course co-developers, have the primary responsibility for supervising the undergraduate students clinical experiences at the professional development school sites. The clinical instructors and master teachers will continue to be involved with the development, evaluation and revision of the courses created throughout the project.

Clinical instructors and master teachers were selected through written applications. Selection criteria were based on past experience and demonstrated leadership in mathematics, science, technology and teacher-preparation projects. Criteria for selection also included interest, enthusiasm, and commitment to improving the teaching of mathematics, science, and technology. Clinical instructors were selected first by project participants and their building administrator and teachers. The clinical instructors then became involved in selecting the master teachers.

Because this is just the second year of the project, the professional development school concept has not been put into full practice. Our vision for full involvement of the professional development schools in the teacher preparation process at Kansas State University is based on 6 major premises:

> **a) Professional Development Schools are based on collaborative relationships between content specialists, education specialists and practitioners. Institutes of teacher preparation and school teachers and administrators need to create new partnerships to improve teaching.**

We plan to implement this first premise by utilizing teachers, clinical instructors and administrators in our program planning, field testing, evaluation and revision. In addition, content and education specialists will become involved in exchange services with the schools. We will all supervise students, observe classrooms, and attempt to put our theories into practice. We also envision involvement in school improvement projects, curriculum development and evaluation, staff development, collaborative research projects and consultation. We intend to utilize our clinical instructors as co-teachers of on-campus content and methods courses and as seminar directors for site-based training. In exchange, the university faculty will occasionally teach K-6 students in the professional development schools.

> **b) Professional development schools are to be utilized to strengthen and integrate practical field experiences. They will serve as sites to integrate theory from professional studies with practice in clinical settings. Fieldwork will be interspersed and aligned with course work.**

Our project focuses on the coordination of content with methodology and field experiences. We will provide school-based seminars where future teachers can reflect on their course work and their field experiences with their peers, master teachers and university faculty. We have created teams to jointly plan and conduct courses and supervise field experience.

> **c) Professional development schools are vehicles to extend the knowledge base in teacher education for collaborative inquiry into**

> **teaching and learning. Outstanding site-based research and action research should be regular features of these schools.**

We intend to research new instructional strategies, arrangements, curriculum materials and teacher preparation techniques under a variety of working conditions. We intend to explore how children learn, how teachers learn and how schools improve.

> **d) Professional development schools are vehicles to encourage experimentation and risk taking. Schools need to be involved in inventing and trying out new practice. Experimentation and sustained evaluation should be an integral component of a professional school.**

We intend for our professional development schools to be sites where teachers, students and university faculty create new knowledge and try out, evaluate and revise practices. Instructional strategies, organizational arrangements, staffing patterns and professional roles and responsibilities will be experimented with as an outreach of our research and evaluation agenda. Ultimately, professional development schools should exemplify the most current and best practices education has to offer.

> **e) Professional development should be a long-term continuous process.**

Professional development schools should, therefore, reflect the lifelong learning of educators. Rather than short-term skill building and "hit and split" one-day workshops these schools will build a growth-oriented ecology. A growth-oriented school ecology is one in which students, practicing teachers, expert teachers, administrators and university partners are all professional learners. As new knowledge is created and practiced, teachers are provided the opportunity to expand their repertoire of teaching strategies based on researched models of instruction. In our project, preservice and inservice teachers will be provided with theory and opportunities for practice, feedback and coaching. The aim will be to create reflective, analytical teachers. Students' achievement will be improved through continuous professional development. We envision our schools providing opportunities for inservice teachers to observe for short periods of release time, for longer sabbaticals or to teach for a number of years. The schools will become laboratories for observation, experimentation, and extended practice.

> **f) Professional development schools are an integral component in the professionalization of teaching. For education to improve, a more professional vision of teaching must be created. Teachers need to be involved in new roles and differential responsibilities. They need to be integrated into goal setting, problem solving, curriculum development, student assessment, teacher preparation, school decisions, instructional and schedule changes, and staff development programs.**

Our program's aim is to create new roles to promote the professional involvement of teachers. Teachers will be clinical instructors, teachers, co-developers and evaluators of the project, seminar leaders, university co-instructors, project decision makers, and supervisors and mentors of student teachers.

Our ultimate goal is to put the premises of professional development schools into practice. Through the 5 year project we will continually evaluate, revise and improve upon our vision of professional development schools. At the end of this project we hope to have a teacher preparation model to disseminate to other institutions based on collaborative partnerships between colleges of education, colleges of arts and sciences and school practitioners. We anticipate that permanent partnerships will be maintained between these groups of individuals for the improvement of the teacher preparation process.

Our three professional development schools will continue to be sites for clinical field experiences, action research, and the continuous professional growth of university faculty, practicing teachers and administrators, and preservice teachers.

Professional Development

Our vision for reform in teacher education requires new roles and responsibilities for all participants at Kansas State University and within the public schools. To effectively implement this vision we have created a comprehensive professional development plan for project participants for all five years of the project. The first project year, 1990-1991, we conducted a number of formal and informal development activities. On a formal basis, we planned activities for clinical instructors, master teachers and administrators within the professional development schools to assist them with their new roles and responsibilities. The three clinical instructors met with faculty on the Kansas State University campus once a week during the spring semester for all-day sessions. They read and discussed articles concerning learning, new visions for elementary science and mathematics, equity issues, cooperative learning, process skills, and staff development.

As a team, the clinical instructors, in collaboration with their master teachers, created a professional development plan for the twenty-five master teachers from the three professional development schools (see Table 1, Professional Development Plan). The clinical instructors planned and conducted six half-day workshops for the twenty-five master teachers based on this plan. These sessions focused on the nature of science and mathematics, process skills in science and mathematics, constructivism, new standards and recommendations in science and mathematics, gender/equity issues, and action research.

A four-week 1991 summer institute was also conducted for teachers, administrators, and faculty as part of participant training. This institute involved twenty teachers and faculty members. The topics covered included: constructivism and the learning cycle in mathematics and science teaching, portfolios, reflective teaching and journaling, and the use of technology in mathematics and science.

During the second year of the project, 1991-1992, all project participants were invited to a series of monthly professional development activities. These have included guest presentations from national and local speakers on a variety of topics related to science and mathematics reform. In addition, we offered school-based workshops and study groups on a number of issues selected from the professional development plan topics. Project participants have been supported to attend and present at local, regional, and national conferences. Additional development options include: teachers and faculty jointly involved in action research on alternative assessment and improving educational equity; field testing new science and mathematics curriculum, pilot projects involving multimedia, telecommunications, and other innovative technology; and curriculum development efforts focused on the "science-mathematics-technology (SMT) after school clubs", and "SMT summer magnet schools." All project participants have also been involved in development activities as a component of the monthly planning seminars.

Table 1
Professional Development Plan

I Professional Development Plan Topics

Reform in elementary science, math, technology education
Current standards, recommendations, and curriculum for Math, Science, and Technology
Learning theory (constructivism) applied to elementary and college classrooms
Creating equitable learning environments at elementary and college levels
Alternative assessment
Learning Styles
Professionalization of Teaching
Changing roles and responsibilities
Peer coaching/mentoring
Action Research
Reflective Teaching
Portfolios
Journaling
Teacher Preparation

II Major Strategies

Constant focus on "partnership" concept
All activities jointly selected and planned by teachers, administrators, and KSU faculty
All activities involve teachers, administrators, Colleges of Education & of Arts and Sciences
Constant use of teachers teaching teachers
Provide many opportunities and constant encouragement (both pressure and support)
Include variety and many options for professional development
Encourage strong district and administrator support

III Formats

Whole group sessions - guest speakers, summer institutes, work sessions
Small group optional sessions - guest speakers, school based workshops
Individualized one to one help sessions
Planning teams
Study groups
Actions research - equity and alternative assessment
Pilot projects - technology (multimedia, telecommunications)
Field testing - curriculum
Campus courses - ENLIST Micros, Logo, hypermedia
Participation in other staff development projects - Math Their Way, TESA
Support to attend and present at workshops - local, regional, national
Curriculum development - mathematics, science, technology summer magnet school and after-school clubs

IV Schedule for Formal and Large Group Sessions

Year 1 -	Master Teacher: one day every other week for one semester Clinical Instructors: one day every week for one semester Monthly planning meetings
Year 2 -	Monthly professional development options Monthly planning meetings

The major focus for all professional development activities has been collaboration and variety. We have attempted to involve all participants in planning, selecting, and conducting activities and to provide a number of optional formats and topics. We have made development plans relevant, individualized, and problem solving in nature. A key goal has been to provide access to resources, information, and support services.

Recommendations

Kansas State University is a member of the Holmes group. This membership has provided a strong incentive for our project. In 1987 the Holmes Group set out to: change the way we educate teachers; help construct a true profession of teaching; cooperate with school people in inquiry that transforms the schools; and restructure their own institutions to achieve these ends. We believe these are powerful goals for the improvement of teacher preparation in general and science and mathematics education in particular.

In addressing these goals, several critical issues emerge related to collaborative efforts to reform elementary mathematics and science teacher preparation. The following list of issues are those which we feel have guided project planning and decision making.

1. Establish meaningful collaborative goals
    a. To improve teacher preparation at Kansas State University and beyond
    b. To improve elementary science and mathematics education within the professional development schools and beyond
    c. To build collaborative and collegial relations between all members of the Manhattan-Ogden School District, the College of Education, and the College of Arts and Sciences.
    d. To help create a true profession of teaching at all levels K-college.
    e. To maximize human potential for all individuals involved.

2. Enhance ownership and personal sense of meaning:
    a. Encourage participation and involvement from all stakeholders
    b. Listen to one another
    c. Create a sense of responsibility for personal, organizational, and professional growth. We are responsible for ourselves but also for one another as a community of learners and for teaching as a profession.

3. Establish a learning community:
    a. Create "real" partnerships. We all need to learn, improve, and grow together.
    b. Integrate college, district, school, and individual needs and goals
    c. Encourage personal and organizational self analysis and problem solving

4. Empower teachers:
    a. Encourage diversification in teaching roles and responsibilities
    b. Enhance collegiality and collaboration
    c. Create an active problem-solving mentality
    d. Provide "power tools" (access to resources, information, and support)

5. Utilize and expand the professional knowledge base
    a. Encourage experimentation and risk taking
    b. Provide opportunities for action research, field testing, and pilot projects
    c. Provide opportunities to study, share, and plan together

6. Address adult learning needs:
    a. Treat teachers and faculty with dignity and respect as professionals
    b. Create long-term and continuous professional developmental plans
    c. Use multifaceted and variable formats for enhancing professional development
    d. Provide time and support for participants to practice new ideas
    e. Encourage strong administrative support at all levels
    f. Build a shared sense of efficacy - together we can succeed.

We recommend that other institutions involved in a reform agenda consider these critical issues and how to address them while considering their own unique set of strengths, weaknesses and environmental and social circumstances. Through this project and attention to these critical issues, the Kansas State University's teacher preparation program has been enhanced, the teaching skills of participating teachers and faculty have been improved, and new collaborative relationships have been established between the College of Arts and Sciences, the College of Education, the Manhattan-Ogden Public Schools, and the local Manhattan community.

As additional institutions of teacher preparation continue to experiment with reform efforts, the knowledge-base concerning the preparation of effective elementary science and mathematics teachers will be expanded. Such efforts will have significant and long-term effects on science and mathematics education in American elementary schools.

INSTITUTIONAL COORDINATION ISSUES

Karen J. Stucky
Indiana University

I was very impressed at the effort the projects described in the conference have made to involve classroom teachers in the planning and implementation of their programs. This effort can and does bring a real credibility, especially for preservice teachers, to a program that they are participating in during their undergraduate years. It also can bring a realistic approach to the kinds of goals that the projects are attempting to reach, that of improving teacher education as well as science and mathematics instruction and learning in the elementary school.

I am full-time sixth grade science and math teacher in the Monroe County Community Schools and have been very active in elementary science inservice training for many years. Consequently I have also been working as the elementary science coordinator for the school system for the past seven years in addition to my classroom duties. During the 1990-91 school year I was granted a sabbatical in order to work with Indiana University and Dr. Dorothy Gabel on the QUEST Project.

My involvement began even before the proposal was completely written and submitted in planning how local classroom teachers could be incorporated successfully into the program. I became one communication link between the "real" classroom and the university. During my year on campus I was active in most of the different aspects of the QUEST Project. I audited three of the science courses that are required of elementary Ed majors and then lent my experience in the revision of these courses. I also helped recruit elementary majors into the area of science, and helped plan and coordinate the Saturday Science program for local fourth, fifth, and sixth graders which is an integral part of this project.

The most important role that I played was to help identify the needs of local classroom teachers in the area of science, help select teachers to participate in the project and direct the two four-week summer workshops as well as the inservice days during the school year. I kept in constant contact with both the university and the participating teachers to share information and produced results. The teachers that are involved in the inservice program are receiving content and methodology information from the university professors that also work with the undergraduate QUEST students and will eventually become the mentor teachers for the undergraduates during their student teaching experiences.

During the Critical Issues Conference, I participated in an informal panel discussion during which I responded to the following questions.

Why must there be a partnership or collaboration?

In order for true changes to occur, there must be ownership at both levels - the university and the public school. When ownership of a program is involved, it is much more likely that such changes will happen and be incorporated into the schools in a more permanent way. Our program is a little bit different as it involves both preservice teachers or elementary Ed majors and several school districts in Monroe Country and some of their classroom teachers. This involvement brings reality and application of subject matter presented in the college classroom to life when an experienced classroom teacher says that this can work with students or makes suggestions on how something can be adapted for the elementary classroom. This kind of collaboration can validate a project especially in the eyes of college students and prove to be both beneficial and valuable to all groups of participants.

How do you increase this collaboration?

Things that encourage collaboration need to be written into grants and proposals from the beginning. The QUEST Project involves 32 teachers from Monroe County, Indiana and their participation in the four week summer workshop for two consecutive summers is rewarded with graduate credit from the university and compensation for their time and effort. The school system has responded by providing facilities, materials, supplies for both the workshop and use in teaching science in the teacher's classrooms and by allowing the teachers to take professional leave days during the school year to attend conferences and follow-up workshops that provide opportunities for communication and discussion of how they are applying the material they were given in their classrooms. This collaboration will continue over the years as these participating teachers will act as the mentor teachers for the science elementary education majors from the university during their student teaching experiences.

What are the dilemmas of such a collaboration?

The main problems that do occur are the lack of time and communication between the parties involved and this must be worked on constantly and carefully. We have been producing a newsletter that is sent to all QUEST people - university faculty, public school teachers and university students. This allows all those concerned to be aware of the things that are happening in classrooms, social events that are coming up and special meetings, conferences, etc. that might be of interest and pertain to elementary science education. Another dilemma that can arise is a change in personnel at any level - in the students at the university who leave school or change majors, university or public school people who are unable to continue in the project for one reason or another and/or administrators who made the original commitments to the project. These problems must be faced and solved as they arise and hopefully will not seriously interfere with the main purposes and goals of the project which are to improve science education at all levels and encourage communication between the university and the local public schools.

INSTITUTIONAL COORDINATION ISSUES

PANEL SESSION 7:
Promoting University Faculty Development

COORDINATING COURSE DEVELOPMENT FOR A UNIFIED PROGRAM

Diane Thiessen
University of Northern Iowa

PROMOTING UNIVERSITY FACULTY DEVELOPMENT IN THE PRE-SERVICE ELEMENTARY SCIENCE/MATHEMATICS PROJECT

Teresa M. McDevitt and Ivo E. Lindauer
University of Northern Colorado

FACULTY DEVELOPMENT AND ENHANCEMENT

Dorothy Gabel
Indiana University

COORDINATING COURSE DEVELOPMENT FOR A UNIFIED PROGRAM

Diane Thiessen
University of Northern Iowa

When the University of Northern Iowa decided to require a subject matter minor for all elementary majors, the mathematics education faculty found that the initial design of the program was made in a relatively short period of time. In the past there had been a three-course sequence for all majors and some courses for a concentration in mathematics that were primarily taken by students who were interested in middle school/junior high. The new program for prospective K-6 elementary teachers was to include a total of 24 semester hours with two courses (6 semester hours) that were taken by all elementary majors. As we discussed the goals for our program we found the NCTM *Curriculum and Evaluation Standards* became the basis of our goals. Course titles and catalog descriptions for the courses evolved smoothly. Later, when we started to write up each course we found more time was needed for planning than was originally allotted.

Goals of Mathematics Minor for Elementary Teachers Program

The courses addressed in this program are designed for prospective elementary school teachers. These include courses designed for all elementary education majors and courses designed for the mathematics minor. The goals for this program are to help the student:

- become a mathematical problem solver
- learn to communicate mathematics
- learn to reason mathematically
- connect mathematical ideas
- learn to value mathematics
- become confident in one's own ability

Content versus Methods? Is that the question?

As we started to look at our individual courses, new concerns emerged. Differences among philosophies about teaching and learning emerged and often centered on content versus methods discussions. It was sometimes difficult to tell how different individual views were. At times it appeared views were similar but the language was different.

Glenda Lappan, a consultant to the PEMST project, proposed that we design and analyze our courses by looking at knowledge that teachers need: mathematics content, instructional activities, and student learning (see Table 1, Notes from Exit Interview). We needed to consider that teacher decision making and practice is guided by knowledge and belief. The diagram in Figure 1 was developed to help design and analyze our courses. This diagram helped shift our focus to looking at explicit components for specific courses. As teachers planned units, lessons, and assessments, the seven areas of the Venn diagram needed to be considered.

This diagram is not as simplistic as it looks. What are good mathematical tasks to help preservice teachers learn new mathematics? And what are good tasks to help students understand the mathematics for which they may have procedural knowledge only? Are the activities for the preservice classroom or for the elementary classroom? Is the thinking about the preservice teacher's thinking about mathematics, about children's thinking about mathematics, or how preservice teachers think about children's thinking? Another layer encompassing the entire diagram is the university teacher's thinking about the preservice teacher's thinking about mathematics, activities and kid's thinking! Although the NCTM *Teaching Standards* were not available for our initial discussions, this latter statement could be perceived as, "How does the university faculty member select mathematical tasks, create an environment, orchestrate discourse, and analyze his/her teaching?"

Collection of Courses versus a Program?

In order to build a program rather than develop a collection of courses, connections among the courses must be made. Communication about the courses is essential in order to develop these connections. Written information in the form of course notes and student evaluations is essential for the faculty to communicate and to build a program.

One individual was designated to develop each course. Originally a mathematics consultant worked with the mathematics educator; but over time some developers started additionally consulting with one or more staff members, leading to increased dialogue regarding some of the courses among some of

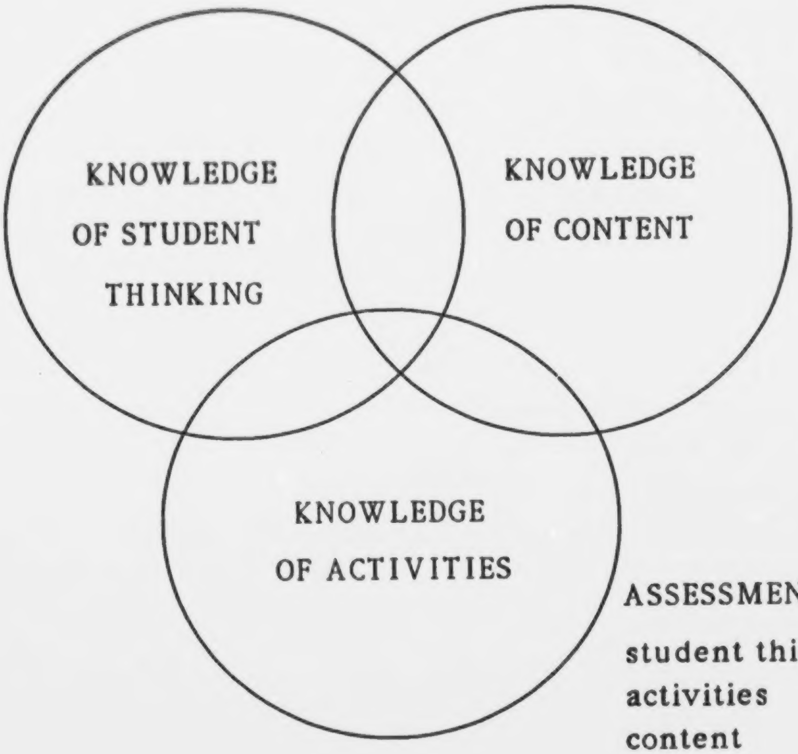
Table 1
Notes from Exit Interview
PEMST Mathematics Consultant Glenda Lappan, Michigan State University:
February 1989

Your proposal:
In what way does this course contribute to:
developing critical thinking/problem solving strategies
modeling problem solving and critical thinking strategies to develop reasoning strategies
develop reasoning abilities
learn to communicate mathematics
integrating content with learning theories and learning cycles
integrating science and mathematics content
integrating technology
developing comprehensive understanding of concepts and processes.
explicitly recognizing, relating, developing and utilizing connections among mathematics ideas.
confidence building
learning to value mathematics

Suggestions:
arithmetic to algebra interface variable
visualization, geometry, analytic geometry
role of verification, proving (argument)
science of patterns
study of variation, invariants
abstracting, inventing, proving, applying
language
reading assignments

Balance-Methods, Content

Knowledge that Teachers Need



ASSESSMENT

student thinking
activities
content

What guides teacher decision making?
Knowledge and beliefs

What guides teacher practice?
Knowledge and beliefs

Figure 1
Venn diagram of "knowledge that teachers need."

the faculty. (With part time adjuncts, we currently have a staff of nine mathematics educators. Although they are not all involved in developing courses, they all have input into the program.)

One dilemma for practically all of the courses was that they were being designed for K-8 teachers and there were no readily available textbooks. For some courses two or three resources seemed to be appropriate; for others it appeared that even that was not available. In order to develop these courses, fairly extensive teacher notes were needed. In this way we could document what materials/resources were being used and how.

Whenever one starts teaching a course for the first time, it is helpful to have information in the teacher notes about previous classes' backgrounds and thinking. Although no class is the same, there are common characteristics from semester to semester. One way of sharing this information is identifying specific content and problems for which students often have difficulty. Vignettes from the classroom that describe different thinking that students have shared helps give a flavor of the class environment and discourse.

Longer time blocks are needed for analyzing courses, discussing programs, and long term planning. To accommodate discussion, prior to the beginning of both fall and spring semester, a retreat is scheduled. We have evolved from 1 1/2 days to 1 day to 2 half-days; the latter appeared to be more effective for our staff as we are still intellectually alive at the end of a "1/2 day". The main requirements are to find a room with no telephone and with comfortable chairs around a table.

We discussed the courses at different stages over the past three years. Currently we are reviewing each course. The original goals of the PEMST project and recommendations by Glenda Lappan were reviewed and written into question format (see Table 2, Course Development and Review). These guidelines can provide a structure for discussion of each course and provide feedback to the course developer. Additional evaluations by the instructor and the students are completed at the end of each course.

Input from Students

Evaluation of our program has been provided by student teachers. Written surveys were sent to all PEMST student teachers. A dinner meeting was held for student teachers within an hour's drive from UNI. Prior to dinner, the

Table 2
Course Development and Review
Mathematics Education Faculty

We all need to take responsibility for all courses. Each course needs to be critiqued. Specific ideas need to be suggested. It is the course developer's responsibility to revise in light of the recommendations. Each course contributes to our total program. Final evaluation of each course will be by the Mathematics Education faculty and then the PEMST Steering Committee.

1. What are the course goals? How do these goals relate to the Program Goals?
2. Does this course contribute to the Proposal Goals (see attachment)? (The developer needs to document.)
3. How are the suggestions regarding concepts and processes (see attachment) integrated throughout the course? (Explicitly note how the first four Process Standards are reflected across the Proposal Goals and Suggestions.)
4. Explicitly how are the *Curriculum and Evaluation Standards* integrated/reflected/studied in this course?
5. Are all sections of the Venn diagram of "knowledge that teachers need" contained in the course (see attachment)? How does assessment address all three components?
6. How are beliefs and values being modeled and questioned? (Each component of the Venn diagram needs to be addressed.)
7. How is this course connected to other courses in the program? (We need a concept map among courses.)
8. What are the mathematical tasks?
9. How does the teaching of these tasks reflect mathematics as a dynamic course of study rather than a set of rules to be memorized?
10. What is the role of discourse with regard to the teacher? . . .students? What tools of discourse are suggested? How do the Teacher Notes reflect the spirit of the *Teaching Standards*?
11. How do the Teacher Notes promote ongoing evaluation of the course and the teaching of the course?

student teachers met as a group and discussed the PEMST program. The meeting was conducted by a mathematics and a science minor; faculty were not present for this part of the meeting. Later the student leaders met with project staff to summarize the student concerns and reactions. After dinner, the student teachers and the science and mathematics education faculty talked over common concerns about the program. The written evaluations and the concerns expressed in both parts of the dinner meeting were tabulated and summarized as part of the evaluation by the student teachers. Both faculty and students have enjoyed participating in the evening; the informal atmosphere and an opportunity to meet has been appreciated by the participants.

Continuing Evolution of Courses

The last several weeks I have pondered the dissemination of course materials. As I listened to different speakers at UNC discuss the fact that programs are not transportable, it seems that disks rather than printed materials should be considered. Courses should evolve over time. A printed copy indicates a finished product rather than a course that changes over time and is adapted to different populations. Changes are needed as textbooks change, students change, instructors change and the individual instructor changes.

Disks can be readily adapted for other's needs as disks are readily edited. Only parts of the courses may be relevant to other universities and those sections can be readily accessed. Additionally, it is cost effective as disks are not as expensive as photocopies nor are they as expensive to mail.

PROMOTING UNIVERSITY FACULTY DEVELOPMENT IN THE PRE-SERVICE ELEMENTARY SCIENCE/MATHEMATICS PROJECT

Teresa M. McDevitt and Ivo E. Lindauer
University of Northern Colorado

Rationale and Objectives

At the University of Northern Colorado, a model program in science and mathematics has been developed and implemented for pre-service teachers. The aims of the program are to cultivate pre-service teachers' understandings of science and mathematics (and their interrelationships), to foster teachers' ability to teach these subjects effectively, and to enhance teachers' confidence and positive attitudes toward these subjects. Science and mathematics were presented in ways that prospective teachers (and their students) find useful and personally relevant. Particular attention was given to ensuring that teachers learned how to motivate *all* students to learn in these areas (including groups of individuals typically underrepresented in professional fields sustained by science, mathematics, and technology). Emphasis was also placed on modeling and advancing teaching methods that encourage students to take an active part in investigations, to learn in a meaningful fashion, to relate concepts to their personal experiences, and to work together in cooperative groups.

University professors associated with the program worked together with "mentor teachers," experienced elementary and middle-level teachers, to revise science and mathematics content and methods courses and an educational psychology course. In their efforts for reform, the faculty members and experienced teachers were motivated by numerous calls for reform. Specifically, professors and teachers worked together to help students move beyond rote learning, a common but ineffective learning mode that so often characterizes fragmented science curricula (e.g., Eylon & Linn, 1988). Instead, they conspired to make learning meaningful for their students, and in so doing, selected content and pedagogy in light of their relevance for students' future teaching assignments (see American Association for the Advancement of Science, 1990, and National Council for Teachers of Mathematics, 1991).

Undergraduate preparation of teachers has been critiqued in numerous reports (e.g., American Association of Colleges for Teacher Education, 1988; Carnegie Forum on Education and the Economy, Task Force on Teaching as a

Profession, 1986; Holmes Group, 1986; National Commission for Excellence in Teacher Education, 1985). Often such analyses have associated with them recommendations for what amounts to a near revolution of the way teachers are prepared. Clearly, individual faculty members working in isolation will not have the desired impact; instead, what is needed are large-scale attempts that bring together faculty members and school personnel who embrace common beliefs about instructional and programmatic remedies. To the degree that pre-service teachers experience a coherent, internally consistent set of teaching methodologies and conceptual underpinnings for these strategies, they will be better able to adopt the strategies themselves in their own teaching.

At the University of Northern Colorado, the Pre-Service Elementary Science/Mathematics Project has been well served by faculty members from both the Colleges of Arts and Sciences and Education. Faculty members from Arts and Sciences (who taught program courses or provided administrative support) came from Biological Sciences, Chemistry and Biochemistry, Earth Sciences, Mathematical Sciences, the Mathematics and Science Teaching Center, and Physics. Faculty members from Education held affiliations in Educational Psychology, Elementary Education and Reading, and the Teacher Education Center. The Teaching Fellows were experienced elementary and middle-level teachers who were recruited through local Colorado districts to participate in a team capacity with faculty members. There were a total of 14 university faculty members who served as the project's Senior Staff; 11 experienced teachers have served the project as Teaching Fellows over the life of the project (typically 3-4 teachers work on campus at a time, with fewer at the beginning and ending of the funding period).

The collaboration of so many individuals possessing distinct perspectives creates many opportunities. Elsewhere we and our colleagues have outlined the many benefits realized by partnerships with experienced teachers (e.g., Heikkinen, McDevitt, & Stone, 1992; Lindauer, 1991; McNerney, 1991). Benefits are apparent to prospective teachers, to the faculty members with which they work, to the teachers themselves, and to their home districts. There are also many benefits to students and to faculty when faculty members from different disciplines and orientations coordinate their instruction with students in mind. For example, in our program it became possible to coordinate some of the topics and techniques across content and methods courses. It also became possible to use themes, content, and examples from one course in another course (e.g., the instructors in the educational psychology course asked students to perform an information-processing analysis of the demands of a lesson introduced in the mathematics methods course, the instructors in the physical science course were able to depend on students' attainment of required mathematical understandings when introducing certain content, and students in the biology course utilized mathematical skills to predict population increases and genetic diversity.) The students themselves mentioned that they appreciated the fact that concepts and approaches were reinforced across courses.

Approaches to Faculty Development

Several approaches were taken to assist faculty members with their attempts to enhance their own instruction of pre-service teachers. First and foremost, faculty members were recruited who were interested in teaching pre-service elementary teachers and who were confident in their own teaching abilities yet were still yearning for improvement. With such a group of individuals, an optimal culture for self-reflection and positive growth emerged. Most of the senior staff were engaged in the actual drafting of the model program at its inception, making the group a self-selected one.

Second, the senior staff and teaching fellows participated in regular meetings, at which time common themes were discussed such as the mathematical skills needed in science courses and possible ways to teach in an equitable manner. These meetings were extremely productive, but it was a great challenge for us to find common free times during which we could meet. The countless demands of university life did not decrease during the life of the project, thus numerous meetings were conducted without the presence of all senior staff members. Yet the communication was important, and it helped everyone broaden their views of teaching and learning. For example, it occasionally became clear to senior staff that certain terms we took for granted have different meanings in different disciplines, and so operational definitions were sometimes needed. For example, "solving problems" or "problem solving" may evoke different images to an educational psychologist, a scientist, and a mathematician. Ultimately, it was critical in terms of program development to discuss central features such as instructional strategies, equity concerns, course sequencing, and reduction and focusing of content.

Third, senior staff members who taught program courses were provided with release time by the National Science Foundation funding and with the support of their host departments. For each course, three to four months of full-time support were offered for the enhancement and revision of the course in line with project objectives (most often this support was given to one individual, but occasionally two instructors team-taught a course, in which case the support was divided between the two). Teaching fellows held half-time assignments on campus and typically focused their efforts on one course (with a secondary assignment to a second course; for their remaining time, teaching fellows coordinated staff development and curricular revisions within their districts and took advantage of graduate courses and other professional development opportunities on campus and within the state). Project experiences in course redesign and program development made it evident to us that significant changes require substantive commitments of time and collaboration between faculty members across disciplines.

Fourth, teaching fellows served an indispensable role in faculty development. The university faculty members associated with the project had the unique opportunity to conduct their course revisions and actual instruction with the assistance of active, experienced classroom teachers. We have described this critical feature of the project in detail elsewhere (Heikkinen, McDevitt, & Stone, 1992; Lindauer, 1991; McNerney, 1991), but can briefly summarize this discussion by stating that experienced teachers, brought in as full and equal partners, have the capacity to serve as productive catalysts for change. They can model effective teaching for students, confirm the value of course content for students, assist faculty in their attempts to pare down and focus concepts, and otherwise instill teacher preparation with grounding in elementary classroom realities.

Fifth, formative evaluation results were presented to senior staff members after they delivered program sections of courses. Although it was not possible to present specific findings related to students' understandings of course concepts, it was possible to present summaries from students (obtained from their written anonymous responses to open-ended questions) of their perceptions of the strengths of the courses and their recommendations for improving them. These results could be used by faculty members as input to their reflections on how to improve the courses.

Finally, we should note that numerous initiatives have been underway in recent years on the University of Northern Colorado campus to support faculty development in undergraduate teaching. For example, the institution is a member of the Project 30 alliance and the Renaissance Group, and other campus entities (such as the Mathematics and Science Teaching Center and Center for Research on Teaching and Learning) have encouraged the refashioning of instruction at programmatic and individual levels. These activities have created a climate that is receptive to innovation and have further bolstered project faculty in their work.

Outcomes/Effectiveness of Approach

A comprehensive evaluation is being conducted to document the program's implementation as well as its effectiveness. To date the findings have been consistently positive (e.g., see Constas, 1991; Constas, Gardner, McDevitt, Heikkinen, & Horton, 1991; Constas, Silverman, & McBride, 1991; McDevitt, Heikkinen, Alcorn, Constas, & Ambrosio, in preparation). Data have been collected from within quantitative and qualitative traditions; students participating in the project have been compared with a similar group of students not in the project but who were also seeking certification in elementary education and who entered the university at the same time as project students. However similar to the comparison group at their entry into the university, project students have become far more confident in their knowledge of science and mathematics and in their ability to teach these subjects. They have also become far more sophisticated in their understanding of ways to encourage all students to succeed in these subjects and they possess a greater commitment to teaching and a more thorough understanding of relationships between science and mathematics.

These results do not directly address the effectiveness of faculty development, but they do suggest that project students have received a coherent message about effective teaching strategies and the many enjoyable features of science and mathematics. We are certain that a range of features is needed to support faculty members in their efforts at change. These include a readiness for change, participation with like-minded individuals, sustained periods of time that can be devoted to reviewing course activities and materials, collaboration with school personnel, comments to faculty members about the in-class success of their "teaching experiments," and broad-based support on campus for change.

Recommendations

The need for monumental changes in teacher preparation in general and in science and mathematics in particular has been articulated by many educators, policy makers, business leaders, and scientists and mathematicians. It is important to recognize, however, that it can be difficult for faculty members to change their teaching methods and reduce their content presentations. It takes considerable time to translate curricular and instructional guidelines into actual lessons and materials for a specific course, and guidance from others is often needed. Ideally, an individual faculty member's efforts would be supported by colleagues on campus as well as by school personnel. In our own experiences, we have found that informal connections cultivated by faculty members across departments are helpful, as are formal mechanisms for communication. We urge other institutions contemplating similar programs to build in specific mechanisms that solidify connections between and among faculty members and experienced elementary teachers. Because of difficulties inherent in convening meetings with large groups of individuals, it may be valuable to require a commitment from interested faculty members that they allocate prolonged periods to working together as a unit during times when teaching and other responsibilities can be contained (e.g., over a summer session). We believe that innovations in teacher preparation cannot be implemented successfully without such collaboration.

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FACULTY DEVELOPMENT AND ENHANCEMENT

Dorothy Gabel
Indiana University

Faculty development occurs at a slow rate just as curriculum changes in schools occur at slow rates. When a faculty member has developed a course over a period of years and has perfected a certain style of teaching, asking him or her to change both the course content and the methods used in the course to a more constructivist, hands-on approach can be met with some resistance. This is especially true when the person has received a teaching award for presenting the course in a traditional way.

One of the objectives of our QUEST Project at Indiana University and that NSF has for many of its Teacher Preparation Projects is that all of the introductory science courses at a college or university be improved through changes in content and/or methodology. Many of the modifications that an institution might implement in special science courses for elementary education majors should also be adopted in these general introductory courses. In fact, if these courses really met the needs of the general population, there would be very little need for separate courses. Although many persons think that it is ideal to have special courses for elementary education majors, separating prospective elementary teachers apart from the rest of the college population might convey the idea that these students are incapable of taking a regular science course. In addition, it is very costly for the university to run special sections of courses, or unique courses, for particular groups of the student population.

At Indiana University, approximately 500 students each year enter the elementary education program. This includes the students who desire to be certified in special education, early childhood education, and elementary education. Consequently we have large numbers of students enrolled in our science and science methods courses. Our program includes three special science courses for these students: Introduction to Scientific Inquiry, Biology, and Physical Science. Our students also enroll in an introductory geology course that fulfills the science requirement of any liberal arts major. The introductory geology courses are quite well taught, and by having one course available that students can transfer into the program, a level of needed flexibility is provided that is essential for a university like ours which has several branch campuses around the State.

In terms of faculty development, how does a university which rewards its faculty for doing research, and in which almost every faculty member has a research grant, encourage faculty members to design and teach a course appropriate for prospective elementary teachers? How do you help faculty members broaden their perspectives about teaching to become cognizant of the changes that are needed in both content and methodology to make the course focus on conceptual understanding rather than covering a large number of facts and concepts? Finally, once course development has begun, how can they be supported to continue to make the changes needed for on-going course development? These three questions form the basis of the comments in the remainder of this paper.

Perhaps the only advantage of having science taught poorly or not at all at the elementary level is that it awakens science faculty members who have children in one of these classrooms to the fact that something must be done to improve elementary science education. One solution for many scientists is to make a presentation in their child's classroom. Another solution, that some come to realize will be more effective, is to teach the science course in their department in which prospective teachers enroll to fulfill their science requirements for the elementary education program. At Indiana University several physicists are very interested in teaching the physical science course; however, fewer biologists are willing to teach the special biology course.

Once faculty members have committed themselves to teaching the specialized course, means must be taken to broaden their perspectives about what changes need to be incorporated into the course to make it more effective. An effective way that the QUEST Project has brought this about is in the choice of members of the Advisory Committee. Persons on our Advisory Committee were deliberately selected with the view that they could assist us with faculty development. They are primarily scientists (biologist, chemist, and two physicists) from institutions comparable in size and reputation to ours, who have national reputations as scientist-educators. Scientists speaking to scientists about effective teaching effects more change than educators speaking to scientists. At Indiana University we made the decision not to bring our whole Advisory Committee together at one time during our first year while we were just getting started. Instead individual members on the Advisory Committee were invited to the campus for two days during which time they presented a seminar or colloquium to the science department faculty, and worked with the scientist on the QUEST team who was developing or revising the introductory course. By scheduling these seminars in the faculty lounge of the physics department and by using interesting titles, we were able to attract about one-third of the physics department faculty members to each presentation. Some even came the following day to ask questions about how they could revise an introductory course not intended for the elementary education majors!

Another factor that can influence change in other introductory science courses is that the changes made in the course for the elementary education majors are effective. At Indiana University we were fortunate in getting the R&D dean and the science departments to cost share the purchase of computers for use in instruction. In the physics department these computers are used to collect and analyze data. The course for the elementary education majors is the only undergraduate course in the physics department for which computers are available. Physics professors are becoming aware of this and are interested in using computers in other introductory courses.

Once science faculty members are willing to make changes in their courses, time must be provided to enable them to do this. The faculty members on the QUEST Project decided that they preferred to be released from other duties half time in the spring rather than quarter time all year. This would allow them to concentrate on course development and there would be fewer other commitments. One might think that the summer would be an ideal time for course development, but this is not the case at our institution. During summers the scientists work on their research grants and proposal writing because they rarely teach and do not have to set aside time to work with undergraduate students. In order to assist them with the course development, a science education graduate student with a masters degree in the particular science discipline was assigned to each science faculty member. This had several benefits. The graduate student could do the library searching that was needed and thus lighten the scientist's load; it gave the scientist someone on whom to try out his/her ideas; the graduate student who was familiar with new teaching methodologies could bring them to the attention of the scientist; and, it helped form deeper bonds between faculty and graduate students in the science departments and in science education.

Once initial changes have been made in a course, other modifications take place as the course is taught. By assigning a graduate student to help with those modifications, the faculty member, who no longer has released time to make the changes, has a support system that makes the revisions more probable. This helps the long-term development that is really needed for effective teaching.

Finally, attendance by several members of a project at conferences like this one at the University of Northern Colorado is effective in sustaining the effort needed to bring about change in the preparation of prospective elementary teachers. Your effort is to be commended.

INSTITUTIONAL COORDINATION ISSUES

PANEL SESSION 8:
Establishing Administrative Support

ESTABLISHING ADMINISTRATIVE SUPPORT

Terry T. Crow
Mississippi State University

ESTABLISHING ADMINISTRATIVE SUPPORT

Carolyn Cody
University of Northern Colorado

THE MISSION AND WORK OF THE RENAISSANCE GROUP

Anthony Evans
California State University-San Bernardino

ESTABLISHING ADMINISTRATIVE SUPPORT

Terry T. Crow
Mississippi State University

The proposal which successfully funded the project at MSU was written by a faculty member in the Department of Physics and Astronomy. The department has been actively working with pre-college teachers and students for more than a decade. Several years ago the University granted permission to this department to fill a position with an individual to work as a science liaison educator whose primary work responsibility is pre-college programs and contributing to the introductory physics teaching program. This is the genesis of the project.

In the planning phase the principal investigator discussed the proposed plan with faculty in the College of Education's Department of Curriculum and Instruction - the home department of elementary education majors. The Arts and Sciences faculty simultaneously discussed topical coverage and teaching strategies for the proposed courses. Since Curriculum and Instruction advisors must place students in the sequence, it was necessary to have them involved in the planning. (Other majors can take the lecture and laboratory to satisfy general University requirements but the course design is aimed at the elementary education major.)

To initiate new courses or to modify present courses the Colleges and the University have curriculum committees which must approve all additions, changes and deletions of courses in the catalog. For many years physics taught a two-semester, three credit hours per semester lecture sequence. This changed to a two lecture hour, two laboratory hour course design and its present form has evolved to a three lecture hour, three laboratory hour per semester sequence. All of this required curriculum committees' approvals. The laboratory content of the present courses was designed in consultation with teachers in the appropriate grade levels during summer workshops. In the physics sequence we list the lecture and laboratory as separate courses; therefore, we must register students for two courses in physics each semester. The biological science course is listed as a single four credit course including lecture and laboratory. There are advantages and disadvantages associated with each approach.

The early discussions were faculty member to faculty member. Within Arts and Sciences it was quickly necessary to involve department chairs to ensure cooperation and coordination. An associate dean in Arts and Sciences was an integral part of this coordination phase. These discussions led to agreements to assign faculty to the courses, to provide the necessary lecture and laboratory space, and to cost share. University overhead rates are determined by external audit for various types of proposals from various units. The business affairs office collects and distributes overhead to the grantee's home department at approximately three month intervals. One portion goes to the Vice President for Research and another to the department in which the grant resides. Once per year we distribute overhead from our account to other departments by budget transfer. These amounts were pre-determined once the grant was awarded (and were negotiated even earlier).

Cost sharing for the grant is supplied by several sources. The Dean of Arts and Sciences funds one graduate teaching assistant fully. NSF will not pay for TAs to teach laboratories but they will pay faculty to train and supervise TAs. (The course lecturers have regular weekly meetings to discuss pre-lab and post-lab problems and questions.) NSF will pay faculty for course/laboratory development but not for teaching courses. We "release" that portion of faculty salaries paid by NSF from state appropriated funds, transfer the released funds to a special account. The TAs are then paid from this account, so the University can show real dollar cost sharing. Some NSF funds are used to pay a part of the TA salaries - they are required to maintain a detailed log and manual for use by future TAs in these laboratories. NSF funds do not pay for the teaching portion of their salaries.

Since the physics laboratory courses carry separate credit and since graduate students from chemistry, education, geology, and physics are listed as instructors of record, graduate students are responsible for assigning grades that will be a part of a student's permanent record. We insist that TAs must discuss these grades with the course instructors.

We will continue the two physics courses and have developed good materials even if the team teaching is not continued.

The faculty member's home department originates all salary and transfer papers. These flow through the grantee's department where the total expenditures are tracked and these papers then go through the Dean's office to business office. The PI oversees the general operation of the grant. This requires that she originate all requests for travel, purchases, etc.

Problems do arise: over a five year period many things will happen. Personnel will change (we have a new dean, associate dean, and provost in just the second year), university priorities may change in times of limited financial resources, and departments with limited resources may have to make difficult decisions about the number and kinds of service courses that can be taught in a given semester. As an operating principle you must assume many things will occur; some will be just inconvenient and others will create major perturbations in the program. But overall we have to believe it is worthwhile making the effort.

ESTABLISHING ADMINISTRATIVE SUPPORT

Carolyn Cody
University of Northern Colorado

For the past three years, the University of Northern Colorado has been involved in Project 30, a national project funded by the Carnegie Foundation. The goal of this project has been to engage faculty in the Colleges of Education and Arts and Sciences in collaboration for the purpose of reforming teacher preparation.

The conversations centered around five themes:

1) What entitles one to be called "teacher"?
2) What is appropriate subject matter knowledge for those who would become teachers?
3) What is "pedagogical content knowledge" and how is it best taught?
4) How can we increase multicultural perspectives in the curriculum?
5) How can we increase the representation of minority group members in the teaching profession?

The thirty institutions selected for this project were invited to create their individual responses to teacher preparation reform. UNC's response became "Teachers for the Future," a curriculum reform and faculty development project which has had a campus-wide involvement.

We are currently in the throes of rethinking the purpose of general education, of determining what it means to be a UNC graduate. Also underway are new programs for teacher preparation which are being planned by faculty from the disciplines in Arts and Sciences, faculty from Education, and teachers from our Laboratory School and public schools, all partners in the planning process. Another step will be to reconsider the shape of the academic major. And equally as important as curriculum reform, we have recognized the need to model better teaching. We are trying to create more formalized instructional support for faculty.

These have been exciting times at UNC! But they wouldn't have happened without leadership: a strong commitment from a variety of faculty and administrators within the institution. A project of this magnitude cannot be undertaken without leadership in the traditional chain of command which will influence those below, and persuade those above. However, informal leadership among peers has been critical in the success we have enjoyed so far.

At UNC, strong academic leadership came from our Deans of Education and Arts and Sciences, who were much stronger as collaborators than they would have been had they represented a single college interest. They were individuals in touch with the national issues and concerns in higher education, as well as those in teacher preparation. They were both committed to UNC's state mandate: a role and mission to provide leadership, collaboration, excellence, and change required. They educated a central administration and a faculty about the need for change.

To initiate any project for change requires such academic leadership. And it can come from a person in any role, really. But regardless of where one starts, education and inspiration and involvement must move both ways.

I want to share with you several steps in gaining support for your projects. And though our topic is administrative support, I will tell you that gaining support of colleagues follows similar processes.

1. There are several important questions to ask about or of your administrators.
   a) What do your leaders value?
   b) Where do they put discretionary resources?
   c) What is the payoff for your department, college, or university for involvement in your project? How do your leaders record a "win"?
   d) Is it local or state publicity? Prestige? And if so, with whom?

It is important to determine what will reinforce their image of what it means to have a successful program, unit, college, or university, then demonstrate how the success of this project will achieve those goals.

2. Use what you've learned to educate your administrators:
   a) How much do they know about NSF, the national goals?
   b) How do these goals support Higher Education goals nationally?
   c) How does your project fit?

   d) Make your project easy for them to understand; do executive summaries.
   e) Use their language.
   f) Make your project meaningful to them.

3. Frame a vision
   a) What will be the impact? What is the "win" for the institution?
   b) How will it happen? Demonstrate its chance to effect change. (Is it collaborative with broad involvement?
   c) Does it have long range planning, ongoing activities, a way to become institutionalized, a resource plan?

4. Create a need for your administrator's expertise.
   a) Give them a real role to play
   b) If you want them in on the landing, you must have them on the take off.
   c) Describe the support you want them to give.

5. Provide ongoing support for your administrators
   a) Collect data that administrators can use (bragging info!)
   b) Reinforce how the success of this project is achieving institutional goals.
   c) Empower administrators to be advocates on your behalf.

As an administrator:
--If I understand what you're doing . . .
--Believe it will carry the institution or unit forward . . .
--If I see it has a high chance for success . . .
--And I have some real role to play . . .

Why would I (or anyone!) turn you down!

THE MISSION AND WORK OF THE RENAISSANCE GROUP

Anthony H. Evans
California State University

The Renaissance Group, a consortium of 16 national universities[*] with notable strengths in teacher education programs, was founded in 1989 to improve further the education of teachers on member campuses and to facilitate efforts to reform teacher education nationally.

A unique feature of the group is the requirement that presidents, academic vice presidents, and education deans of each campus be actively involved in its work. Such a representative structure helps mobilize university-wide support for the education of teachers and adds credibility to the organization.

The Renaissance Group has formally adopted a set of principles which guides its work. The principles that follow are both statements of best practice as currently seen in quality programs for the preparation of teachers and objectives to be achieved within colleges and universities that strive for a quality program for the education of teachers.

1. The education of teachers is an all-campus responsibility.

2. Programs for the preparation of teachers thrive in a university culture that values quality teaching.

3. Decisions concerning the education of teachers are the shared responsibility of the university faculty, practitioners, and other related professionals.

4. The initial preparation of teachers is integrated throughout a student's university experience and is not segmented or reserved to the student's final year.

5. The appropriate role of the state is to establish outcome expectations for teacher education graduates; the appropriate role of the

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[*] Universities belonging to the Renaissance Group include: University of Alabama at Birmingham, Ball State University, California State University, San Bernardino, Eastern Michigan University, Emporia State University, Georgia Southern University, Illinois State University, Middle Tennessee State University, Millersville University of Pennsylvania, Norfolk State University, University of Northern Colorado, University of Northern Iowa, Towson State University, Western Kentucky University, Winthrop College, and the University of Wisconsin-Oshkosh.

university is to determine the curriculum, standards, and internal policies for teacher education programs.

6. Rigorous learning expectations and exit requirements characterize the program to educate teachers.

7. The academic preparation of teachers includes a rigorous general education program, in-depth subject matter preparation, and both general and content-specific preparation in teaching methodology.

8. Teacher education programs reflect American diversity and prepare graduates to teach in a pluralistic and multi-cultural society.

9. The education of teachers incorporates extensive and sequenced field and clinical experiences.

10. Quality teacher preparation programs have faculty who are active in scholarly and professional endeavors.

11. The continuing professional development of teachers and other education personnel is the shared responsibility of the university faculty and other education professionals.

12. Programs to educate teachers for the new world have sufficient support to implement these principles.

The Renaissance Group is already engaged in a variety of activities targeted at improving the education of teachers. Its action agenda includes activities on member campuses to familiarize professional colleagues with the above principles and to harness the immense talents on each campus for improving teacher education programs. It pursues a multi-university research agenda on critical issues affecting the education of teachers. It also works closely with other professional groups and associations and with elected officials and key public policy makers in order to influence the development of legislation and policies for improving both education programs at universities and teaching in the schools.

Although still a young organization that limits its membership to one key university per state, the Renaissance Group is gaining visibility nationally and is expected to make increasingly significant contributions each year to the effort to adapt the preparation of teachers and actual teaching in the schools to the growing challenges presented by a new and markedly different generation of students.

ETHNOGRAPHIC SUMMARY

AN INTERPRETIVE ACCOUNT OF A CONFERENCE ON THE PREPARATION OF ELEMENTARY TEACHERS OF SCIENCE AND MATHEMATICS

Kenneth G. Tobin
Florida State University

AN INTERPRETIVE ACCOUNT OF A CONFERENCE ON THE PREPARATION OF ELEMENTARY TEACHERS OF SCIENCE AND MATHEMATICS

Kenneth Tobin
Florida State University

Approaches to the education of elementary teachers have changed a great deal during the past 20-30 years. When elementary teachers were trained in teachers' colleges there were opportunities for specialization in content areas such as science and mathematics in contexts where special science and mathematics courses were designed for prospective elementary teachers. Accordingly, the content courses were tailored to the needs of the learners, taking account of their backgrounds and their vocational preferences. Furthermore, it was also possible to build courses that took account of a relatively weak background in science and mathematics (especially in the physical sciences) of prospective elementary teachers. When teacher education began to be absorbed into comprehensive universities there was a concern that prospective elementary teachers study *legitimate* science along with majors in other non-science areas. Comprehensive universities (as distinct from those based on a vocational preference such as teaching) provided greater choice than was possible in teachers' colleges and a trend developed for elementary teachers to opt for the minimum amount of science and mathematics and where possible to avoid advanced studies and subjects such as physical sciences and calculus (Weiss, 1987).

Throughout the world, parallel changes have occurred in the preparation of elementary teachers. Within universities it has become necessary for faculty in colleges concerned with the preparation of teachers to reach out to colleagues concerned with teaching mathematics and science. Since, in many universities mathematics and science courses are no longer focused on the needs of teachers, problems have arisen in terms of the courses prospective elementary teachers choose to study and the manner in which these courses are taught and learned. The evidence suggests that prospective elementary teachers frequently have little idea of mathematics and science as a process and have images of teaching and learning which incorporate lectures, talk, chalk, textbooks, and paper and pencil quizzes. Classroom studies suggest that many elementary teachers teach science through the use of lectures and textbooks (Goodlad, 1984; Tobin & Fraser, 1987).

The teacher education community is becoming increasingly aware of the catastrophic inadequacies of mathematics and science learning in the United States. Many have looked to the elementary school for the solution to the problems. It is evident that elementary teachers do not have strong backgrounds in mathematics and science, and in the case of science, little time is allocated in the elementary school curriculum (Loucks-Horsley et al, 1989). Inevitably teacher education has become a focus for reform. In some states such as Oregon legislative actions have virtually wiped out colleges of Education in many universities. Fortunately, in all states, federal grants have made it possible for university educators to collaborate with others to understand and improve the quality of teacher preparation programs.

The purpose of this chapter is to describe what was learned from an interpretive investigation (Erickson, 1986) of a conference which was intended to bring together college professors and administrators with the principal investigators of projects funded by the National Science Foundation to enhance teacher preparation programs in elementary mathematics and science.

Background Information

Procedures. When I was invited to be conference ethnographer I did not have any preconceived notions of what that might entail. I agreed to undertake the task because I had used ethnography in my research for approximately 10 years and felt that I might learn to look at the education of prospective elementary teachers in a new and exciting way. Furthermore, I knew and respected the organizers of the conference and felt that my involvement might in some way enhance the conference. Their suggestion to have an ethnographer was novel to me, and as I traveled to the site of the conference in Northern Colorado my mind actively pieced together scenarios in which I enacted a variety of roles. By the time I arrived I had formulated a set of goals for myself:

- To describe what happened at the conference from the perspectives of participants.
- To explain why particular events occurred as they did.
- To describe changes that were observed throughout the conference.
- To evaluate the conference from the perspective of providing an environment in which participants can learn and reflect about teacher education.

By the time I reached the conference venue I had formulated the following questions for the conference organizers.

- What were the expectations of participants?
- What learning occurred during the conference?
- What network possibilities have been created?
- What was the response of the participants to the sessions?
- What is the summative perception of the worth of the conference?
- What were their reflective thoughts about the worth of the conference?
- What changes are planned and implemented as a result of participating in the conference?

At each session at the conference I listened and watched attentively, making notes on a laptop computer. These notes were fleshed out after the events of the day, usually late in the evening. To augment my field notes I requested participants to write me notes in relation to each session, asking them for their opinions of what happened and any related points they wanted to convey. These handwritten notes were a data source for the study.

It soon was apparent that my role was perceived by many at the conference to be an evaluator who would provide formative data to the conference organizers. Accordingly, many of the notes were requests to make changes to the manner in which the conference was organized and implemented. I assumed this role, passing on to the conference organizers any information that I felt would assist them to improve the quality of the conference.

Subsequently I sent a request to all participants, asking them to provide me with additional details that were pertinent to the meeting. The idea of making such requests was to ascertain their reflective thoughts on the conference and the extent to which they felt that networks had been established.

Researcher's beliefs. I perceived my role to be one of formative evaluator and synthesizer of what was presented. As an ethnographer, however, I also was obligated to describe what was happening and why it was happening as observed. Accordingly, it is wise for me to clarify my apriori beliefs that pertain to my task of observing and describing what happened and then interpreting observations to infer why the observed events occurred as reported.

As the organizer of a major international conference on the History and Philosophy of Science and Science Teaching in 1989, I was strongly of the view that conferences should be participants' conference rather than presenters' conferences. I did not value sessions where a presenter occupied most of the time to present information to those in attendance. On the contrary, I believed that presenters should use methods to actively engage participants in activities through which they can learn. This belief influenced what I looked for when I attended the sessions, what I hoped I would see, what I recorded as relevant, and when I received feedback from participants, what I noticed and about which I ultimately informed the conference organizers.

My beliefs about knowledge and knowing are constructivist in nature, being best described as critical constructivism, incorporating socio-cultural perspectives on learning. In essence, I believe that learners are responsible for making sense of their experiences and ought to have equal power with others with whom they interact in learning situations. Interaction, whereby participants have opportunities to negotiate meaning can enhance learning and involves negotiation and consensus building. If the program does not make opportunities available for participants to interact socially, then learning can only be enhanced if participants create their own interactions.

Data Analyses. The data analyses occurred approximately 12 months after the conference. The reason for the delay was not to place a time distance between me and the data, but because of other priorities that needed immediate attention. However, during the time of the conference and the writing of this chapter, I have been intensively involved in the reform of a teacher preparation program at Florida State University. Many of the issues raised at the conference have personal meaning for me and have undoubtedly influenced the nature of this report.

The analyses consisted of reviewing the data sources and asking the question what happened here? Categories began to emerge as I reviewed the sources. At first I was struck by a dichotomy between substantive and structural issues. The substantive issues fell into two broad groups: learning to teach; and science and mathematics content learning. Similarly, the structural factors related to the courses developed and implemented during the projects and the presentations at the conference. The creation of data involved an initial sort of phrases and notes from my field notes and notes provided by participants into the above four categories. Close examination of the data within each category allowed me to construct assertions clustered within the four categories listed above. The emergent assertions then provided a referent for re-examining the data sources, and in the process, creating data for and against each assertion. This process led to assertions being refined such that the wording was consistent with all of the constructed data.

Triangulation, in this study, was based on the use of multiple data sources for each assertion. For each of the assertions presented in this paper, I used field notes and evaluation forms from numerous participants in the conference. Analyses of documents produced by the planners and presenters at the conference also enabled data to be created and used in the support, refinement, and refutation of assertions.

What transpired surprised me. The responses from the participants were almost all to do with the structure of the conference. They constructed me as an ethnographic evaluator with a role to mediate between them and the conference organizers. I accepted this role because it seemed reasonable and because I believed that the provision of feedback to conference organizers would lead to a better conference. Formative evaluation in the form of verbal assertions supported by data from participants would be of value to the conference organizers who would then be able to take actions to make changes to facilitate the conference.

My belief that this role would diminish in importance was not supported by the events of the conference. The participants, seeing that I took their comments to the conference organizers, continued to provide comments that focused primarily on the organization and implementation of the conference. Few comments focused on the substance of the conference.

Chapter overview. This chapter contains two additional sections, the first focusing on the implementation of the conference and the second focusing on the critical issues that emanated from the conference.

Implementation of the Conference

My first set of notes for a discussion with the conference organizers contained the following discussion agenda: leave dinner intact; increase time for breaks; restructure concurrent sessions; focus presentations on critical issues; encourage more interaction; restructure sessions to begin with small group discussion on the critical issue. Similar issues arose on every day of the conference and several trends were soon evident with respect to structure of the conference.

- There were too few opportunities for interaction. This was a presenters conference rather than a participants conference.
- The daily program was too long.
- The program structure allowed too few opportunities for informal networking.
- Overhead transparencies were not used to facilitate learning.
- A paradox that was not lost on participants was that different learning models underpin the teacher education curricula being described and the presentations of the conference. The focus of presentations was on disseminating too much content in the time allowed. Lecture was the predominant presentation method.
- When changes were made, participants welcomed the use of alternative presentation methods which increased interaction.
- The focus of presentations was on projects rather than the critical issues. Issues were not identified and discussed among participants.
- Important networks were established.

Events of the day can often prove to be a distraction to participants in any activity, and unfortunately this was the case during the conference. As well as the lure of fine weather every day, breathtaking scenery, and television coverage of college football on Saturday, a daily drama enticed many of the conference participants away from the concurrent sessions. Direct telecasts of the Thomas versus Hill sex discrimination case presented an unfolding controversy that engaged crowds who gathered around a large screen television in the lobby of the conference facility.

Within this conference there was a strong feeling among participants that the emphasis was on science as opposed to mathematics, and accordingly, that the benefits of their participation were not as great as might have been expected. The expectation that the discipline specific nature of critical issues in education of prospective elementary teachers led to a mind set that the conference agenda was not as relevant as it might of been and an unwillingness for participants to construct themselves as learners or to acknowledge that something could be learned from sessions conducted by science educators. The critical issue to arise from this finding is whether or not there are content specific differences that prevent something learned from mathematics teacher education, for example, being applicable in science teacher education.

A parallel problem was a dichotomy that seemed to be established between presenters and participants. There was a strong feeling expressed that the expertise of participants was ignored at two levels, by the presenters and by the conference program. This problem seems to have been exacerbated by an impression that the presenters represented themselves as experts with little to learn from others at the conference.

Throughout the conference there were concerns at the manner in which presenters engaged participants. I provided the conference organizers with ongoing feedback on this aspect of the conference and efforts were made to involve participants to a greater extent as the conference progressed. However, it is important to realize that the success of a conference session is just as dependent on the participants as it is on presenters. Throughout the conference I had a feeling that some of the participants had constructed themselves as being on the periphery of events. This surfaced from time to time in the notes sent to me in relation to the conference. A frequent complaint was that too many of the sessions focused on science education and were, therefore, of little importance. Alternatively for other participants, sessions were generic and of little relevance. For example, in the plenary session presented by Hilda Borko it was very evident that many in the audience had not constructed themselves as learners with respect to the speaker. There was evidence of an undercurrent of dissatisfaction at having a session as late as this one, and by a person who was a teacher educator rather than a science or mathematics educator. Several participants seemed to have constructed themselves as experts rather than learners and were not cooperative in the interactive components of the speaker's presentation. The speaker had clearly planned the session to focus attention on vignettes which were drawn from earlier sessions at the conference.

The following excerpts from my field notes of the conference provide an illustration of the extent to which the audience was prepared to participate interactively in the session when given a chance.

> Hilda asked a question part way through her talk and stunned the audience into silence. They had to identify elements of pedagogical content knowledge in a vignette drawn from the work of a colleague who had presented earlier at the conference. Two persons respond but the remainder are silent. One of these persons raises an issue about the wisdom of giving a student the type of problem being discussed.

Essentially the issue was whether or not it was necessary to provide experience with cookies before asking children to divide cookies among their family members.

Another example is now provided by Hilda. There seems to be some mirth among some of the group. What is going on here? The two women who challenged Hilda about the cookies seem somewhat dissatisfied with the talk so far. Are other mathematics persons feeling the same way? It seems so. Do they perceive her as being out of field with respect to mathematics and teaching mathematics? Hilda asks another question of the group. They are ready now and an answer is forthcoming. The presentation is interactional, a good sign given what has been said previously. The questions and interactions continue as might be anticipated with a group of this size. Hilda concludes that the teacher in her vignette is a competent beginner. The dissatisfied look appears again in the non-verbal exchange between the two women.

Hilda is setting up another vignette. She readies the group for the task. This is a more difficult task. The group does not seem to be as alive as it was previously. Hilda gives the verdict and an audible derogatory remark emanates from one or two people, both of whom I infer are mathematics educators.

Critical Issues

A number of speakers spoke about reform of curricula. It was evident in their presentations that the teacher is a critical ingredient of the reform effort. If changes are to occur, as society expects, then it will be for teachers and others from the educational culture to learn and adapt. Bybee used the analogy of exercise programs to focus our attention on the problems of teachers failing to sustain reform initiatives. Why don't people remain in exercise programs? They know that exercise is good for them and they commence with good intentions of staying in the program. Bybee argued that in asking teachers to participate in the reform of science curricula we are asking teachers to have a new lifestyle and will need to provide them with the support needed to sustain their efforts.

Teacher education efforts cannot be approached in isolation from other efforts at reform in science education. For example, the National Science Teachers Association is involved in an attempt to reform science curricula from grades K-12 so that there is articulation through the grades to: teach every science discipline every year; build understandings of science from descriptive to theoretical; coordinate the learning from one level to the next; cover less content and focus on developing greater understanding of what is learned; and to eliminate tracking. How are current approaches to teacher education taking account of this major initiative which, even if it is not adopted as an entity, will certainly impact thinking and the evolution of science teaching practices in schools?

An important point made by Brunkhorst in relation to reform was that, if we are to succeed, it is necessary to deal with the whole system at the same time. Accordingly, we cannot deal with the education of prospective teachers without dealing with the education of practicing teachers at the same time. Brunkhorst also emphasized the significance of at least three roles of teachers: classroom leadership (inside the classroom); curriculum policy developer (outside the classroom); and professional learner and leader.

New Science and Mathematics Courses

Issues focused on the development of new science courses for prospective elementary teachers arose as particularly critical because elementary teachers are regarded as generalists and have to teach all subjects to the students they teach. This constraint raises a significant challenge to those involved in teacher education. Most prospective elementary teachers come to their teacher education with minimal background in science, usually having avoided physical sciences and the more advanced types of mathematics (e.g., pre-calculus) to the extent possible. Not only have prospective teachers usually avoided science and mathematics, but usually they have not been successful in the courses they have taken and perceive science to be a body of facts to be learned by rote from textbooks or teachers. Furthermore, many have a negative attitude toward science and because only a few courses are required in teacher preparation programs are likely to graduate with much the same background and attitude as they brought with them to their studies. Accordingly, there has been a concerted effort in many universities to develop more appropriate courses for prospective elementary teachers.

Amount of content. The amount of science and mathematics required of prospective elementary teachers appeared to vary considerably from one project to another. For example, at Kansas State University the minimum number of hours of science and mathematics is 12 semester hours (i.e., 6 semester hours of each) with 6 semester hours of methods courses (i.e., 3 semester hours of each). However, the project at Kansas State University has developed a program for specialization in mathematics and science which includes 32 hours of science, mathematics, and technology courses designed specifically for elementary education majors. Nine hours of methods courses in science, mathematics, and technology also were developed.

Class size. One of the more significant impediments faced by faculty endeavoring to develop more appropriate Arts and Sciences courses for prospective elementary teachers was having Arts and Sciences faculty and administrators accept the smaller class sizes that were required. For example, in one project, there was resistance from biology faculty to offering a biology course to a class of 25 prospective elementary teachers when the normal class size for introductory biology was 1500 students. The faculty did not perceive the teaching of such a course to be a wise investment of faculty resources.

Scheduling of courses. One potential problem in designing special courses for prospective elementary teachers is to arrange for a schedule for them to be offered on a regular basis. At Indiana University, the approach was to develop a sufficient number of courses so that there was only a need for a given department to offer a course every other year.

Course development teams. Most projects described how course development teams were used in the development of new courses for prospective elementary teachers. For example, the course development team for an earth science course contained a geologist, astronomer, physical geographer, meteorologist, etc. The toughest job appeared to be reducing the amount of content to be covered in an integrated course. Each team member wanted his/her own content in the course and it took a long time to reduce it all. This seemed to be a problem that generalized to all course development teams. The needs of the discipline seemed to be considered first as course content was listed, sometimes in terms of chapters from the textbook. In many instances course developers were reluctant to take into account the needs of learners or to begin courses with what the learners knew. The needs of the discipline were invariably the starting out point in constructing a curriculum. What seemed to elude many course development teams was the dialectical relationship that occurs between course content and the learning of individuals. Learners have no choices. They must begin to make sense of what they are to learn in terms of what they already know. It seems a priority for the future to identify ways to enable the knowledge of learners to mediate the intended content of planned courses for prospective teachers. Perhaps one way to facilitate this as a goal is to include past students on course development teams.

Project presenters reported some initial difficulties in getting the course development teams to work together and that it was particularly challenging to have the teams focus on learning rather than coverage and transmission of content. The learning models underlying their traditional approaches to thinking about teaching and learning science were frequently alien to the approaches advocated in the courses being redeveloped.

In one project it was reported that, among the mathematics education group, differences among philosophies about teaching and learning emerged and often centered on content versus methods discussions. It was difficult to see how different individual views were because the language used to describe similar types of activity was different. However, language has within it theoretical underpinnings. For example, a person who advocates discovery learning might feel that s/he advocating something quite similar to another who is advocating problem centered learning. However, until the objectivist beliefs underpinning discovery learning are juxtaposed alongside the constructivist underpinnings of problem centered learning, the deep philosophical differences lie dormant, usually to appear at the time when the curriculum is implemented.

To make headway in the development of courses in this project, the coordinators decided to focus on the knowledge that elementary teachers would need to teach mathematics. The faculty agreed that a distinction could be made between a collection of courses and a program. They would therefore design a program to make connective links between the constitutive courses and focus on the knowledge needed by elementary teachers to effectively teach mathematics. Among the questions they carefully considered are: What are good mathematical tasks to help prospective teachers learn new mathematics? What are good tasks to help students understand the mathematics for which they have procedural knowledge only? Are the activities for the preservice classroom or for the elementary classroom? Is the thinking about the preservice teacher's thinking about mathematics, about children's thinking about mathematics, or how preservice teachers think about children's thinking?

Teaching of mathematics and science courses. A theme which permeated all of the presentations was the desirability of teaching prospective teachers using similar methods and approaches advocated for use with their own future students. This goal created problems in most projects because traditional methods are the antithesis of the goals of would-be-reformers. Based on a model of teaching large classes to memorize facts and algorithms about science, the traditional methods emphasized a transmission model of learning which featured lectures, note taking, and learning from textbooks. Professors who had been taught with traditional methods and had taught that way in the past, often had difficulty in seeing why change was necessary. Accordingly, an issue that was discussed at length in the conference was the difficulty of getting good teachers for science and mathematics courses. One novel suggestion that had merit was that previous students might be effective teachers of science and mathematics courses for prospective elementary teachers, especially if team teaching arrangements could be utilized.

One particular tension concerns the use of lecture and textbook in courses for prospective science teachers. Science educators have seemingly always recommended hands on learning with an emphasis on laboratories and understanding rather than learning of science facts by rote methods. Teachers are exhorted to teach science in ways that maximize active engagement of students. Thus, teacher educators see a paradox. Prospective teachers are not taught the way they are being asked to teach. Little wonder, it is argued, that beginning teachers go out and perpetuate traditional methods of lecture and coverage of content from textbooks, preparing students for tests which emphasize science facts.

Collaboration. The most integrative issue for this conference was the development of professional practice communities to enhance the education of teachers. The key to the development of professional practice communities is collaboration between a wide variety of professional scientists, mathematicians, science educators, mathematics educators, and other educators. In this process of collaboration, mentor teachers emerged as a significant innovation. Although the idea of mentor teacher meant different things in different projects, a powerful idea was that elementary teachers could plan university science courses with professors and assist in the implementation such that significant improvements occurred in the professor's teaching. Thus, mentor teachers from the K-5 school system were used to facilitate cultural change in universities. At the same time university personnel and students were assisting teachers in their K-5 classrooms to improve curricula in science and mathematics. The cooperation provided a milieu that was ideal for learning to teach elementary school science and mathematics.

Collaboration between Colleges of Education and Colleges responsible for the content of science such as Arts and Sciences, Engineering, and Agriculture was seen as an essential ingredient in the reform of teacher education programs. However, to establish interdisciplinary teams of faculty from different subject matter disciplines is a necessary but insufficient condition for collaboration. There is evidence that faculty from different colleges might not respect the work of one another and might not interact in groups in a collegial manner. To be in a collaborative relationship usually requires faculty to construct themselves as learners in relation to those with whom they are interacting and to seek strategies for enhancing the learning of others in the group. It is also important for individuals to construct others as colleagues from whom they might learn.

Possible problems can be anticipated when persons, for example from a science education department in a college of education, take a lead in obtaining financial support from the National Science Foundation to reform courses in science and mathematics for prospective elementary teachers. The problem is, of course, the perception that someone from outside of an area is recommending changes to someone else's courses. An implicit judgment has been made that there is a problem that needs to be remedied, even though there might be no consensus on what the problem is, or that it is the courses that must be changed. Often, faculty in Colleges of Arts and Sciences see the problems as being with the students, and feel that if only students were better prepared for tertiary level science learning, the problem would be solved. However, more often than not, contemporary approaches to the reform of science for prospective teachers have emphasized the necessity to change the approach to teaching and learning those courses as well as the nature of the courses themselves. Thus, there is a tension from the outset. Those who have the official responsibility for the courses, professors in the College of Arts and Sciences, believing that the quality of the students is a major problem and those with the official responsibility for students, professors from the College of Education, believing that the approaches to teaching and learning have to change. Underlying the reforms envisioned by each group is the notion that others have to change what they customarily do.

How does collaboration grow from a situation in which potentially collaborating parties each believe the main changes belong elsewhere? A potential pitfall is to focus on establishing a change agenda too early in an effort at reform. If there is no agreement on what has to change there is a potential for superficial attempts to change, or even worse, unproductive argument and hostility. It is clear that negotiation and consensus building are essential components of collaboration. However, it is an oversimplified view of learning and change to expect that beliefs about the nature of the problem can be negotiated to a congruent consensus among all collaborating parties without the collaborative processes being grounded in endeavors to change. The processes are not linear and causal but dialectical and mutually adaptive and interactive.

If reform efforts are to be sustained over time it is essential that different sets of beliefs are considered from the outset and that faculty with opposing beliefs are not excluded from efforts to collaborate. Initial collaboration between a set of like minded individuals might, in the short term, result in a faster beginning to curricular reform, however, in the long term, it will be necessary to consider the beliefs of all faculty with a stake in teacher education. The long term gains might favor involving faculty on the basis of their long term strategic importance in continuing reform initiatives rather than for reasons associated with the coherence of the beliefs of those involved. Clearly there needs to be a balance in terms of these two points of view. One would not want to have dysfunctional groups because of an inability of faculty to negotiate and reach consensus on critical issues. There is evidence that, in the search for funds for projects, there is a pressure to have multidisciplinary groups involved in reform, who have a priori, determined a plan that is considered to be right by those who review proposals. This pressure to get the right composition of the collaborating team, the right approach to change, and the results to be produced, has a potential shortcoming in that the negotiations needed for sustaining reform after funding might not occur.

Sustaining reform. Some important questions concerning the extent to which reform can be sustained within a culture were raised during group discussions at the conference. For example, what happens to a project at the end of funding from the National Science Foundation or some other source? Initially the teams created during the life of the program can continue to sustain the reform in the university, however, faculty move on to other projects and other universities. What can be done if one of the collaborating departments changes its priorities and is no longer interested in maintaining special courses for prospective teachers? Is it unreasonable to revert to traditional methods of teaching if the approaches and content agreed on in the new courses are not valued by faculty who were not involved in the development of the new courses? Questions such as these are inevitable but do not necessarily bode for a gloomy future. External funding should only be seen as getting a process in motion which will allow faculty to review courses for prospective teachers in an on-going way such that they are responsive to the changing university culture which will include students and faculty. From a constructivist perspective, we ought not assume that courses will be implemented in a way that is separate from the culture. On the contrary, the implemented curriculum will reflect the culture at any given time. We should anticipate that what comes from external funding is an opportunity to establish a history of collaborative goals and course building, to establish collaborative networks within an educational system, and to allow individuals to develop trust and respect for the ideas of others within their universities even if they are in different colleges and departments. Of course if the collaborative teams cease to exist, then over time the networks will cease to function and courses which were set in a particular pattern will evolve to another shape. It is for universities to ensure that once established, collaborative arrangements between colleges and departments continue in a substantive manner with the goal of improving the education of prospective teachers.

There is evidence that the type of university might make a difference in relation to how faculty from different colleges view one another. Science educators hold the view that colleagues in Arts and Sciences do not see themselves as having a primary interest in teaching and do not construct themselves as learners when they interact about teaching. At the bottom line, the belief that is implicit in the actions of some Arts and Sciences faculty is that everyone knows about teaching, but specialist knowledge is needed to know about science and mathematics. Similarly, Education faculty perceived science and mathematics courses as being taught badly, and in many cases, they believed they had answers for the problems, which were being ignored by Arts and Sciences faculty. Little attention was given to what was happening in the science and mathematics classes and why that was happening. Accordingly, the solutions being advocated was often seen as revolution rather than adaptation. It is critical that the design of the reform efforts include a program of interpretive research focused on what is happening and associated reasons for sustaining traditional practices. Rather than having research as one of the bases for reform, persuasive rhetoric is the favored course of action in most of the projects.

Integration. Many reports have called for the integration of science and mathematics. If this is to be accomplished in K-12 curricula, it seems important to provide opportunities for prospective teachers to learn mathematics and science in an integrated way. However, there is evidence to suggest that there is resistance from some faculty in Colleges of Education in particular to the integration of science and mathematics. This appears to be based on a fear that integration will result in loss of professional identity for the faculty rather than potential benefits for prospective teachers or K-12 learners.

Learning of science and mathematics content is obviously an important issue for prospective elementary teachers and those involved in teacher education. There seems to be a consensus on the desirability of integrating science and mathematics within schools and universities. However, it is not clear what is meant by integration and few examples were offered at the conference. When this goal is seen in relation to the difficulties that faculty have in deciding what content to omit from a physics course for prospective elementary teachers, or what balance of chemistry and physics to include in a physical science course, questions arise about the extent to which the goal can be realized in today's universities. Mathematics and the various sciences usually are housed in separate departments in all but the very smallest of universities. Collaboration becomes more difficult because the faculty who meet to plan and implement courses do not know one another well, and in many cases represent the needs of their own discipline in what is seen as a "turf war".

In contrast, the integration of lecture and laboratory within traditional subject areas seems to have been accomplished in a number of projects. The rationale for so doing is partly from a learning point of view and partly from an interest perspective. However, by adopting an approach that utilizes equipment and problem solving, prospective teachers have an opportunity learn in an environment that has much in common with the way they will be asked to teach elementary students.

Reward structure. A significant concern for faculty from colleges of Arts and Sciences is whether they will be penalized for getting involved in teacher education projects. In most of the universities represented at the conference, there was concern that departmental and college level peers and administrators would see their role as being to teach, provide service and undertake research in the area of mathematics and science, not in the areas of mathematics and science teacher education. Although many faculty are permitted to be involved in collaborative efforts in teacher education, their involvement is seen as an extra and does not count towards merit pay or promotion. Thus, at the departmental and college levels, the incentives might not be there to encourage faculty to get involved in mathematics and science teacher education projects. This seems to be a pervasive concern even though university level administrators might support involvement during a grant and ensure that participants will not be disadvantaged during the funding cycle. Two questions that persist after the conference are how do you assure yourself and your colleagues that they will really be rewarded for this? Will those rewards continue after the grant ends?

Learning to Teach Science

Professional practice communities. Many of the projects reported at the conference were involved in the development of professional practice sites which allowed teacher enhancement to be linked closely with teacher preparation. The essence of professional practice schools involves faculty and graduate students from the university collaborating with school personnel to assist in the improvement of K-12 curricula in schools. Teachers usually are assisted to improve their teaching on site. Typically, university personnel observe teaching and facilitate reflection on practice for the teacher through discussions of what seemed to be working and what was not working as well. Other benefits included teaching of model lessons and bringing equipment and supplies to be used in specific lessons.

In the professional practice schools, the boundaries between the schools and the university began to blur and in several cases teachers worked directly with university personnel to improve the quality of teaching and learning in university courses. Teachers participated in the life in the universities in a number of ways that included being members of course development teams, writing lessons and lectures, attending class and critiquing what happened, reviewing videotapes of classes, and team teaching with college professors in their science classes. For example, at Northern Colorado, elementary teachers facilitated change in professors' teaching by working on campus with faculty for a complete year, assisting them with teaching methods similar to those employed in elementary schools. In this project the professors were encouraged to teach prospective teachers using the same methods and approaches they are expected to use with their own future students.

Mentor teachers. The mentor teacher program instituted by the University of Northern Colorado serves as an illustration of how benefits are distributed over the project, school district and the individuals involved. Mentor teachers are able to share strategies such as cooperative learning, hands-on/minds-on activities, and motivational and questioning techniques. The mentor teachers also serve as a sounding board for senior staff as they determine what content would be most appropriate for prospective teachers. One of the mentor teachers from the program noted that:

> In addition, mentor teachers provide a reality check about the day-to-day occurrences in an elementary classroom and lend credibility that what is being taught at the University is indeed what will become essential for survival and success in an elementary classroom. Professors relate that through their interaction with mentor teachers, they have become greater risk-takers in experimenting with different teaching styles. Their desire to learn more about and practice what is being initiated in the current research on the teaching and learning process has also increased.

The school district benefits from releasing mentor teachers to contribute to the professional development of prospective teachers in three main ways. First, the quality of new teachers is improved; second, the mentor teachers return to the school with a new lease on life, energy, and knowledge; and third, often the mentors are able to assume new roles, such as being lead teachers.

Field experiences. The need for early and continuous field experiences was recognized in most projects, the most significant challenges being how to focus the experience on the content areas of science and mathematics. Prospective teachers also participated in professional practice schools in a variety of ways that created an environment in which they could learn to teach science through active involvement with "real" teachers and students. These included observing lessons; team teaching; teaching individuals, small groups and whole classes; assisting with administrative tasks; and grading papers. While prospective teachers were gaining experiences in these ways, they were also providing services to the school and allowing teachers to undertake professional practice activities.

A significant and persistent problem is how to ensure that the experiences in the field support the learning from courses. Teachers who work with students during student teaching are involved in workshops at the university. Two areas of concern deal with the pre-student teaching experiences and the student teaching experiences. The group at Northern Iowa developed a summer program for supervisors so that all field experiences could occur in classes regularly taught by someone who was familiar with the university program and could support its goals. They also developed a mentoring system to assist teachers in their first year of teaching. These approaches are just a part of what is involved in other projects which have endeavored to establish professional practice communities built on collaborative activities involving schools, universities and the community at large.

Because science is not taught regularly in many elementary classrooms, a problem frequently encountered is that prospective teachers do not have many opportunities to teach science during their student teaching and pre-student teaching experiences. One approach that has considerable promise is to arrange a program of Saturday science for elementary students. Such a program allows prospective elementary teachers to gain experience in teaching science to elementary children. At the same time there is an opportunity to target at risk students in a project that has significant potential to provide a needed community service.

The focus in teacher education on the learning of prospective and practicing teachers allows new emphases to be highlighted. First, learners must begin with what they already know and build new knowledge from that base. Second, the learning process needs to be reflective and it is imperative that the approach to student teaching be reformed to allow prospective teachers to learn to teach science and mathematics by extensive field experiences which are augmented by reading of the professional literature, and analyses of their own teaching and learning. Not only should we provide prospective teachers with time to think about their teaching and conduct analyses, but we should also utilize peers and faculty to facilitate the processes of reflection. If the processes of curricular reform, initial teacher education, and the education of practicing teachers, are seen as a part of one enterprise within a professional practice community where learning about teaching and learning is valued, prospective teachers ought to find an ideal environment in which to learn the pedagogical content knowledge which is needed to teach.

Beginning teachers. The problems new teachers face when they enter the workplace was recognized in some projects, and project staff endeavored to develop support and professional growth activities for graduates during a year of induction. This seems to be a significant area that needs attention. Not only are there substantive problems in assisting teachers to adapt to a culture which is in many respects foreign to them, but there are logistical problems in keeping track of graduates who might seek employment throughout the nation, or might not obtain employment immediately after graduation. This important component of improving the quality of science and mathematics education might be best handled through collaborative efforts between school districts and universities. Accordingly, induction programs might be designed for new teachers who had received their initial teacher preparation elsewhere under the aegis of a different university.

Use of technology to enhance learning to teach. The sessions involving the use of technology to improve the teaching and learning of prospective teachers were the most popular at the conference. The participants wrote a great deal about the hands-on format and the multiple opportunities they had to interact with the presenters.

The use of hypermedia appealed to the conference participants as a way to engage teachers in new ways of learning to teach. By allowing a wide variety of information about teaching and learning to be incorporated into an integrated package, learners have opportunities to reflect on teaching and learn by analyzing teaching segments and associated information related to lessons (such as plans), student data (counselor's opinions on specific students, test scores, student work books, etc.), and teacher information (e.g., administrator and student attitudes toward particular teachers). Hypermedia brings convenience to the challenge of learning to teach. If suitable software and hardware is produced to provide information in a form which can be retrieved and manipulated conveniently by prospective and practicing teachers, then the opportunities to learn about teaching science and mathematics appear endless. The essence of this hypermedia is that teacher education and students bring their extant knowledge to learning situations, and in the process of learning use it to make sense of their experiences. Through the use of the media learners are able to determine that teaching and learning in classrooms are very complex processes and that there are ample opportunities to improve practices of teachers and students. The potential for using this media in teacher education programs appears to be enormous, however, at this time the potential has not been fully researched.

Pedagogical content knowledge. One of the most significant of the critical issues raised at the conference was pedagogical content knowledge (PCK). There is little controversy over the importance of this subject, but more than a little confusion about the nature of PCK. It was clear that the development of PCK is a goal for most all of the participants at the conference. However, is PCK to be acquired or is it to be constructed within individuals? From a constructivist perspective PCK is a socially negotiated form of knowledge that is constructed by individuals. How then should individuals go about building PCK? How is it best learned? How can it be represented? Answers to questions such as these seem central to understanding the potential roles of teacher educators in facilitating the acquisition of PCK by prospective teachers. However, in large part the conference did not deal with such matters. For example, in her presentation, Hilda Borko described PCK in terms of an overarching conception of what it means to teach a subject; knowledge of instructional strategies and representations for teaching particular topics; knowledge of students' understandings and potential misunderstandings of a subject area; and knowledge of curriculum and curricular materials.

Three points which emerged as significant in Borko's talk are discussed below. The first involved the nature of the student teaching experience. Should student teachers be engaged in full time teaching so as to get a feel for what real teaching is like? Conventional wisdom says yes to this question. But what of the learner wanting to construct PCK? Borko argued against student teachers being full time in classrooms on the grounds that they need time for reflection which includes analyses of their experiences and synthesis of what they have learned in the field with what they have learned elsewhere. Once again, from a constructivist perspective the argument for focusing the student teaching experience on learning is strong. What is the rationale for having students teach full time, making them busy so that they become exhausted and unable to cope with the meetings, discussions and reading that might be central to the process of learning, and the construction of PCK?

The second point of significance in Borko's talk involved the issue of supervising teachers. Too often supervising teachers are not what teacher educators would want them to be. This sets up a situation where student teachers find a large gap between what is advocated in the university and what they experience in the schools. According to Borko, mentor teachers must be selected for their knowledge and interests in teacher education as well as the teaching of their K-12 students. The issue is broader than just selecting good teachers. It seems to me that mentor teachers should be integrally involved in the teacher education program and that teacher educators should be just as involved in the K-12 program. The establishment of professional practice communities offers a solution to the problem of locating well educated teachers who see themselves as teachers of teachers. It is clear that there is even more involved. The mentor teachers need to see themselves as teachers with respect to prospective teachers, but also to construct themselves as learners with respect to others in their professional practice community, including the prospective teachers.

The third significant point made by Borko was that knowledge is socially, not individually, constructed. Perhaps the most salient feature of this assertion is the relation that no living being can isolate him or herself from his/her socio-cultural milieu, even for a second. Everything that is learned is saturated and enriched by the influence of culture, through the use of language and by the meanings given to the signs of a social organization. Thus, it is axiomatic that learning is social, yet so many think of learning in relation only to those who do the learning. Focusing on the social dimensions of learning acts as a reminder that cultures pass on knowledge. But how does this occur and what form does the passed on knowledge take?

Our images of teaching and learning are a form of knowledge that is passed on by the culture. We view others teach and learn, and as we reflect on our observations we reconstruct images to which language is assigned. The words we use and the images we construct have their genesis in experiences and conversations with teachers and learners, who belong to a culture. Accordingly, we build our own knowledge on knowledge that is based on our experience with the culture of teachers and learners. This knowledge provides a basis for our earliest attempts to teach, however language allows us to refine the knowledge and to shape the images in ways that increase the likelihood that knowledge of teaching will be tailored to the culture in which teaching and learning are to occur. Each of us is able to reconstruct knowledge in such a way that the knowledge is shaped, through reflection, by our personal referents and other personal (albeit social) experiences.

The process of making sense of experiences associated with teaching is a complex process which essentially involves data reduction. What we choose to remember and what we choose to ignore is important and is associated with our goals and core beliefs about knowledge and power distribution within organizations. These beliefs are represented in what we believe about learning and the roles of teachers and learners in the classroom. When we think about classrooms we only attend to those experiences that we deem to be relevant. Thus, the forming of categories from experience is an important part of learning to teach. The creation of metonymies is a significant component of making sense of experience. That is, deciding what is central and what is peripheral is an important process in learning from experience. Discussions which follow observations of teaching can be beneficial because they provide opportunities to form categories from experience and to discuss alternatives at a time when the experiences are fresh and reconstructed image building can readily occur. Accordingly, the opportunities to discuss experiences with professional colleagues is seen as a priority in the development of professional practice communities and the education of prospective elementary teachers. If professional colleagues cannot be present personally to interact with the learner teacher, then interactive media, such as videodiscs, sheets of questions to consider, and opportunities to think quietly about what has happened can be beneficial. The purpose is to reconstruct images, form categories of experience, search for alternative relevant categories, and consider possible changes to be effected in given situations.

Metaphor is another important cognitive tool to be used in thinking about teaching and learning. Teacher and learner roles can be represented as metaphors, which in turn act as organizers of sets of beliefs and actions. Thus, as a part of the process of reflecting on teaching it is possible to represent knowledge of teaching in the form of metaphors and associated beliefs and actions. If teachers become aware of the metaphors they use in the process of conceptualizing roles for teachers and learners and for making sense of other aspects of teaching and learning then it is possible to ask questions about the advantages and disadvantages of specific metaphors. It is often desirable to ask about the limitations of using particular metaphors in a range of different situations. Thinking along these lines can result in metaphors being adapted and replaced in certain situations. Thus, identifying metaphors, reflecting on their adequacy, constructing different metaphors, and considering alternative ways of representing knowledge of teaching can be an important component of building PCK.

During the conference there was some evidence to suggest that PCK was taken as a piece of jargon, a new fad that would soon fade away. Why is it important to have such a label for the knowledge needed to teach particular content? Is it important to know that this is an example of PCK and this is an example of content knowledge? These examples and questions might have set up a situation in which participants exclaimed: Who cares! However, there is an argument that labeling the category of knowledge gives it a status that attracts attention and allows teacher educators and policy makers to focus their attention on teachers getting the support to build PCK. PCK becomes the professional knowledge of teachers and for this reason the use of a separate label is justified.

Dissemination. A question that all projects had to address is what can be disseminated to others who are faced with similar problems. This problem is vexing because of the situation-specific nature of teaching and learning. On the one hand we want to pass on our experience so that others can benefit from our labors and the investment of public agencies such as NSF in promoting research and development in teacher education. On the other hand, we have learned that courses must take into account who is teaching them, the students who come to them, and in particular what students do and do not know, and what is considered relevant in the sense that, at the bottom line, the knowledge is needed to promote the learning of science by elementary children. Even within a university it is not clear what is of most use to those who will next teach a course. There was widespread agreement at the conference that a syllabus does not communicate the essence of a course. Textbooks were often not available, but in any event teacher's marginal notes were likely to be of greater value than the textbook per se. For the project at Northern Iowa, classroom vignettes that described different thinking that students have shared, assisted to provide a flavor of the classroom environment and discourse. Other ideas which were not mentioned at the conference, but which have been used on our program at Florida State University, include the use of a journal by the teacher and students, and the use of portfolios to document what happened in the course.

At Florida State University we have addressed the issue of how to describe a curriculum so that others can learn some of the important elements of it. We advocate that lessons be broken up into activities and for each activity to describe the tasks, the interactions, and the knowledge required to accomplish the tasks. The tasks take the place of the more frequently used chapter or topic outline. The focus here is on what students are required to do. The interactions illustrate that learning is a social process and that many of the most important parts of a course will be what happened in terms of interactions involving students, the teacher, and materials. The knowledge needed to accomplish the task is an acknowledgment that there might be several routes to completing any given tasks, each route needing different knowledge. This category of the analysis scheme also highlights the interconnected nature of relevant knowledge.

Research on teacher education. The research agenda for teacher education is enormous. Indeed there appears to be little research being conducted in teacher education. The policy decisions seem to be based on common sense knowledge of those in authority positions. Such people may or may not involve others in their decisions. In each of the critical areas identified above there is a need for systematic inquiry to investigate what is happening, why it is happening, and how to facilitate improvements. Finding out what works and what does not from a variety of perspectives seems to be a high priority for teacher education. One surprising outcome of this conference was the small number of projects that had built in a research component. This situation undoubtedly reflects the policies of the funding agency, although in recent times there is evidence that NSF is now prepared to fund research on teacher education.

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APPENDIX A
CONFERENCE AGENDA

Critical Issues in Reforming Elementary Teacher Preparation in Mathematics and Science

An NSF-Funded National Conference
October 10-13, 1991
University of Northern Colorado

AGENDA FOR THURSDAY, OCTOBER 10

RAMKOTA CONFERENCE CENTER

2:00 pm	Registration Area	**CONFERENCE REGISTRATION**
4:00 pm	Beaver Creek	**RECEPTION** Hosted by the University of Northern Colorado's College of Arts and Sciences and College of Education
5:00 pm	Plaza I and II	**OPENING REMARKS** Introductions: Kathryn Cochran, Conference Coordinator *Gene Hall, Dean, College of Education* *Roger Kovar, Dean, College of Arts and Sciences* *Kenneth Tobin, Conference Ethnographer* **INVITED ADDRESS** Introduction: Henry Heikkinen, MAST Center Director New Curricula in Elementary Mathematics and Science: What Are the Critical Issues? *Shirley M. Frye, Past-President, NCTM* *Rodger W. Bybee, Acting Director, BSCS*
6:15 pm	Plaza I and II	**DINNER**
7:15 pm	Plaza I and II	**WELCOME** *Steven Hulbert, UNC Interim President* **PROJECT OVERVIEWS** Chair: April Gardner, Conference Coordinator *Dorothy Gabel, Indiana University* *Emmett Wright, Kansas State University* *Sandra Harpole, Mississippi State University* *Teresa McDevitt and Henry Heikkinen, University of Northern Colorado* *Robert Ward, University of Northern Iowa* *Pat McClurg, Joe Stepans, and Ron Beiswenger, University of Wyoming*
8:30 pm		**CLOSE**

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AGENDA FOR FRIDAY, OCTOBER 11

UNC UNIVERSITY CENTER

8:00 am Club Bentley **CONTINENTAL BREAKFAST**

TEACHER KNOWLEDGE ISSUES

8:30 am Pikes Peak **PANEL SESSION 1**

DEVELOPING TEACHERS' MATHEMATICS AND SCIENCE CONTENT KNOWLEDGE

Chair: Sandra Harpole, Mississippi State University

Ron Beiswenger, University of Wyoming

Ron will describe the development, pilot testing, and revision of three science courses (earth, physical, and life science) for elementary education majors.

Jay Hackett and Chuck McNerney,
University of Northern Colorado

Course revision in earth science and mathematics focused on cooperative learning strategies, hands-on student involvement, coordination of mathematics/science content, and reducing the "content burden" through teaching fewer topics in greater depth.

Bill Parker and Dean Zollman, Kansas State University

Bill has created and taught mathematics courses designed specifically for prospective elementary teachers. Since 1978 Dean has taught a physics course which is based on the learning cycle and enrolls over one hundred elementary education majors.

Cathy Olmer, Indiana University

Cathy will describe the modification of her physical science course for elementary education majors, which included devising new laboratory exercises to utilize technology which develop students' understanding of physical science concepts.

10:15 am Fireplace Lounge **BREAK**

10:30 am *See Below* **CONCURRENT DISCUSSIONS**

Visit with Panel 1 members to discuss specific courses. Syllabi and course materials will be on display.

Spruce A	*Ron Beiswenger*
Spruce B	*Jay Hackett and Chuck McNerney*
Spruce C	*Bill Parker and Dean Zollman*
Aspen A/B	*Cathy Olmer*

AGENDA FOR FRIDAY / PAGE 2

UNC UNIVERSITY CENTER

11:45 am Mt. Evans **LUNCH**

1:00 pm Pikes Peak **PANEL SESSION 2**

DEVELOPING TEACHERS' PEDAGOGICAL KNOWLEDGE

Chair: Emmett Wright, Kansas State University

Jeanne Ormrod and Kathy Cochran,
University of Northern Colorado

An educational psychology course has been re-designed from a constructivist perspective. Course features include integration of pedagogy with examples from science and mathematics, treatment of socialization issues associated with females and other underrepresented groups, and alternative methods of assessment.

Cherin Lee, University of Northern Iowa

Cherin will describe a science methods course that builds on pedagogy modeled in prerequisite content courses. This course offers students who have learned via learning cycles a chance to teach learning cycles.

Rick Silverman, University of Northern Colorado

A mathematics methods course has been revised to address how children of different ages learn mathematics, how girls and boys can be encouraged to excel in mathematics, and how mathematical understanding can be enhanced with manipulatives and other activities. Analyses of numerical data from scientific phenomena are featured throughout the course.

Joe Stepans, University of Wyoming

Joe will describe education seminars designed for elementary education majors in which students interview children about science concepts, identify their preconceptions, and review related literature. He will also describe the science methods course in which students plan lessons which address children's preconceptions.

2:15 pm Fireplace **BREAK**

2:30 pm *See Below* **CONCURRENT DISCUSSIONS**

Visit with Panel 2 members to discuss specific courses. Syllabi and course materials will be on display.

Spruce A	*Jeanne Ormrod and Kathy Cochran*
Spruce B	*Cherin Lee*
Spruce C	*Rick Silverman*
Aspen A/B	*Joe Stepans*

AGENDA FOR FRIDAY / PAGE 3

3:45 pm	Pikes Peak	**PANEL SESSION 3** **DEVELOPING A COHESIVE PROGRAM** Chair: Teresa McDevitt, University of Northern Colorado *Pat McClurg, University of Wyoming* The University of Wyoming elementary teacher preparation project requires collaboration among university faculty who teach content courses, faculty who teach pedagogy courses, and state elementary teachers who serve as mentor teachers for the project. Pat will describe how these three components have been integrated into a new undergraduate program at the University. *Sandra Harpole, Mississippi State University* The three-semester integrated science sequence is team-taught by faculty from physics, chemistry, geology and biology. Material will be presented in logical sequence by experts in each area with application to follow in the science methods class. *Jack Wilkinson, University of Northern Iowa* The University of Northern Iowa project involves the development of a 26-semester hour science minor and a 25-semester hour mathematics minor for elementary teaching majors. The minor programs are coupled with student teaching experiences supervised by cooperating teachers who have completed three-week summer workshops at UNI. Jack will describe the coordination of all the program elements. *Gail Shroyer, Kansas State University* The Kansas State University project utilizes the advice of Goodlad, Boyer, and the Holmes Agenda in the development of an exemplary elementary teacher education program. Gail will describe how project staff have worked with faculty in arts and sciences, education, and with public school teachers in the creation of an integrated elementary teacher education program.
5:00 pm	Fireplace Lounge	**RECEPTION** Hosted by the University of Northern Colorado's Center for Research on Teaching and Learning (CRTL)
6:00 pm	Mt. Evans	**DINNER**
7:00 pm	Mt. Evans	**INVITED ADDRESS** Introduction: Charles Fisher, CRTL Director The Integration of Content and Pedagogy in Teaching *Hilda Borko, University of Colorado, Boulder*
8:00 pm		**CLOSE**

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AGENDA FOR SATURDAY, OCTOBER 12

UNC UNIVERSITY CENTER

8:00 am Club Bentley **CONTINENTAL BREAKFAST**

SPECIAL ISSUES IN TEACHER PREPARATION

8:30 am Pikes Peak **PANEL SESSION 4**

UNDERREPRESENTED GROUPS IN MATHEMATICS / SCIENCE

Chair: Dorothy Gabel, Indiana University

Gregory Stefanich, University of Northern Iowa

Greg Stefanich is currently the president of the Science Association for Persons with Disabilities. Physically handicapped individuals tend to receive limited instruction in science, are generally advised not to consider scientific careers, and often receive instruction which is not academically adequate to allow them to pursue a science major at the university level. Suggestions for more effectively meeting the needs of these students will be shared.

Mike Fitzgerald and April Gardner,
University of Northern Colorado

The UNC project includes a new undergraduate course, "Equity Issues in a Technological Society." Within a workshop setting, inequities in science and mathematics are examined in terms of their nature and scope, socialization origins, and equitable teaching strategies.

James Copi, Madonna University

Madonna University's Science Teacher Education Program (STEP) seeks the recruitment of minority students into the teaching of science in the elementary school (K-8). Jim will describe recruitment and retention strategies and the benefits derived from a summer vestibule program.

John Halcón, University of Northern Colorado

Since very few elementary teachers speak a second language, they are unable to provide comprehensible input to limited and non-English speaking students. As a result, these students do not perform up to their capabilities. This presentation will address literacy in mathematics & science as applied to these children.

9:45 am Fireplace Lounge **BREAK**

AGENDA FOR SATURDAY / PAGE 2

10:00 am	*See Below*	**CONCURRENT DISCUSSIONS** Visit with Panel 4 members to discuss how various projects address the issue of creating greater opportunities for women, minorities, and physically disabled individuals.
	Pikes Peak	*Greg Stefanich*
	Pikes Peak	*Mike Fitzgerald and April Gardner*
	Spruce C	*Jim Copi*
	Aspen C	*John Halcón*
11:00 am	Pikes Peak	**PANEL SESSION 5** **TECHNOLOGY IN SCIENCE AND MATHEMATICS EDUCATION** Chair: Bob Ward, University of Northern Iowa *Elizabeth Goldman, Vanderbilt University* The Vanderbilt project focuses on the improvement of science and mathematics content and methods courses for prospective elementary teachers. Elizabeth will demonstrate how these instructors use interactive videodiscs to provide a classroom context for the study of teaching and learning mathematics. *Dean Zollman, Kansas State University* Dean uses interactive video for some of the learning activities in a physics course for elementary education majors. He will describe the development and use of interactive video as a component of this course. *Deborah Ball, Michigan State University* Deborah is the co-director (with Magdalene Lampert) of the Mathematics and Teaching through Hypermedia (MATH) project. She is exploring the use of new technologies to create tools for use in teacher education and research on teaching. The project is experimenting with constructing new learning environments for teacher education by linking video images of exemplary mathematics teaching with analyses of lessons that examine both pedagogy and mathematics content. *Kathleen Fisher, San Diego State University* Students who used SemNet™ to organize their biology knowledge in a computer-based semantic network acquired knowledge construction skills and made significant gains in deep processing and elaborative processing.
12:30 pm	Panorama Lounge	**LUNCH**
1:30 pm	*See Below*	**CONCURRENT DISCUSSIONS** Visit with Panel 5 members and view demonstrations of materials and software.
	Pikes Peak	*Elizabeth Goldman*
	Pikes Peak	*Dean Zollman*
	Columbine A	*Deborah Ball*
	Columbine A	*Kathleen Fisher*

AGENDA FOR SATURDAY / PAGE 3

INSTITUTIONAL COORDINATION ISSUES

3:15 pm Pikes Peak

PANEL SESSION 6

SCHOOL AND UNIVERSITY COLLABORATION

Chair: Joe Stepans, University of Wyoming

Jack Wilkinson, University of Northern Iowa

The UNI project included three-week summer workshops for cooperating teachers who supervise the student teaching experience of project students. Jack will describe the organization and format of these workshops, as well as a special mentor-training program for teachers who will work with UNI graduates in an induction year program.

Pat McClurg, University of Wyoming

Pat will describe how project mentor teachers model and coach undergraduates in targeted teaching strategies, as well as the steps the University is taking to include the mentor teacher component in all elementary major programs.

Bj Stone, University of Northern Colorado

Mentor teachers have played an influential role in the UNC teacher-preparation project. These experienced classroom teachers, who help develop, deliver, and revise project-related courses, also serve as role models for prospective elementary teachers and as in-service leaders in their own school districts.

Nancy Thompson and Gail Shroyer,
Kansas State University

Nancy and Gail will discuss the creation of professional development schools. This aspect of the Kansas State project includes enlisting elementary teachers as co-developers of college-level science and mathematics courses, placing student teachers with specially trained cooperating teachers, and establishing positions for clinical instructors who are employed half-time by elementary schools and half-time by universities for instructing clinical experiences for prospective teachers.

Karen Stucky, Indiana University

Karen will discuss advantages of including local teachers in teacher preparation programs—for updating teachers' science backgrounds and for advising college science course revisions.

5:00 pm Panorama Lounge

RECEPTION

Hosted by the University of Northern Colorado's Mathematics and Science Teaching (MAST) Center

6:00 pm Panorama Lounge

DINNER

Informal, special-interest discussions

7:30 pm

CLOSE

Critical Issues in Reforming Elementary Teacher Preparation in Mathematics and Science

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AGENDA FOR SUNDAY, OCTOBER 13

RAMKOTA CONFERENCE CENTER

8:00 am Plaza I and II **CONTINENTAL BREAKFAST**

INSTITUTIONAL COORDINATION ISSUES

8:30 am Plaza I and II **PANEL SESSION 7**

PROMOTING UNIVERSITY FACULTY DEVELOPMENT

Chair: Pat McClurg, University of Wyoming

William McMahan, Mississippi State University

Since science teachers tend to teach as they were taught, we are retooling our instructional style. Workshops and seminars were provided that dealt with student motivation, active learning, questioning techniques, critical thinking, and the need to teach science content in a more participatory format.

Diane Thiessen, University of Northern Iowa

Diane has worked with UNI mathematics faculty in the development of a unified approach to the design and teaching of mathematics courses for the mathematics minor for elementary education majors. She will describe this process and its results.

Teresa McDevitt and Ivo Lindauer,
University of Northern Colorado

Key factors in fostering collaborative reform among UNC project faculty have included release time for course development and enhancement, participation in professional-development seminars, the sustained influence of mentor teachers, and support from campus administrators.

Dorothy Gabel, Indiana University

Dorothy has guided science faculty through revisions in the lecture and laboratory for courses in biology, physical science, and geology. She will describe how workshops on instructional strategies extended beyond the immediate faculty involved to their departmental colleagues.

9:45 am Plaza I and II **BREAK**

AGENDA FOR SUNDAY / PAGE 2

RAMKOTA CONFERENCE CENTER

10:00 am Plaza I and II **PANEL SESSION 8**

ESTABLISHING ADMINISTRATIVE SUPPORT

Chair: Henry Heikkinen, University of Northern Colorado

Terry Crow, Mississippi State University

Terry is the chair of the department in which the principal investigator of a teaching project is housed. He will discuss the general administrative details of the project including cost-sharing, overhead distribution, and front-end negotiations among the departments.

Carolyn Cody and Gary Galluzzo,
University of Northern Colorado

Carolyn and Gary will describe the key features of a responsive administration and will suggest strategies that faculty can use to establish and maintain administrative support for change.

Anthony Evans,
California State University-San Bernardino

The Renaissance Group was conceived and established as a President-Dean organization devoted to strengthening teacher education programs. Tony is one of the founders of this group and currently serves on its Executive Committee. He will describe the function of the Renaissance group and how member universities support their teacher preparation programs and faculty.

11:15 am Plaza III **BRUNCH**

12:30 pm **CLOSE**

APPENDIX B
CONFERENCE PRESENTERS

CONFERENCE PRESENTERS

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